Control ENGINEERING

INSTRUMENTATION AND CONTROL SYSTEMS

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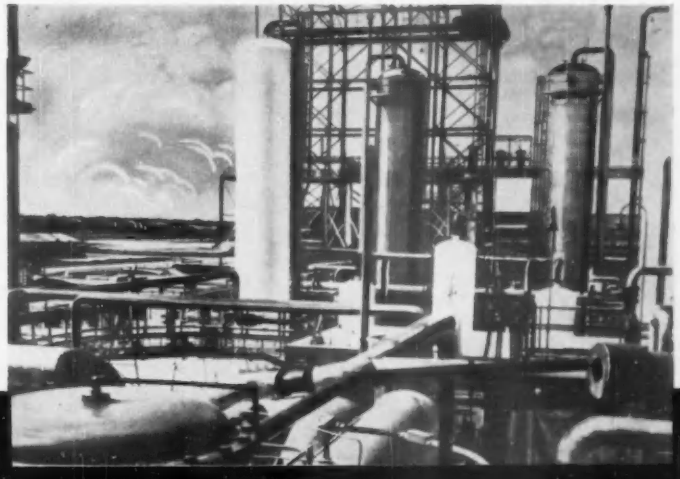
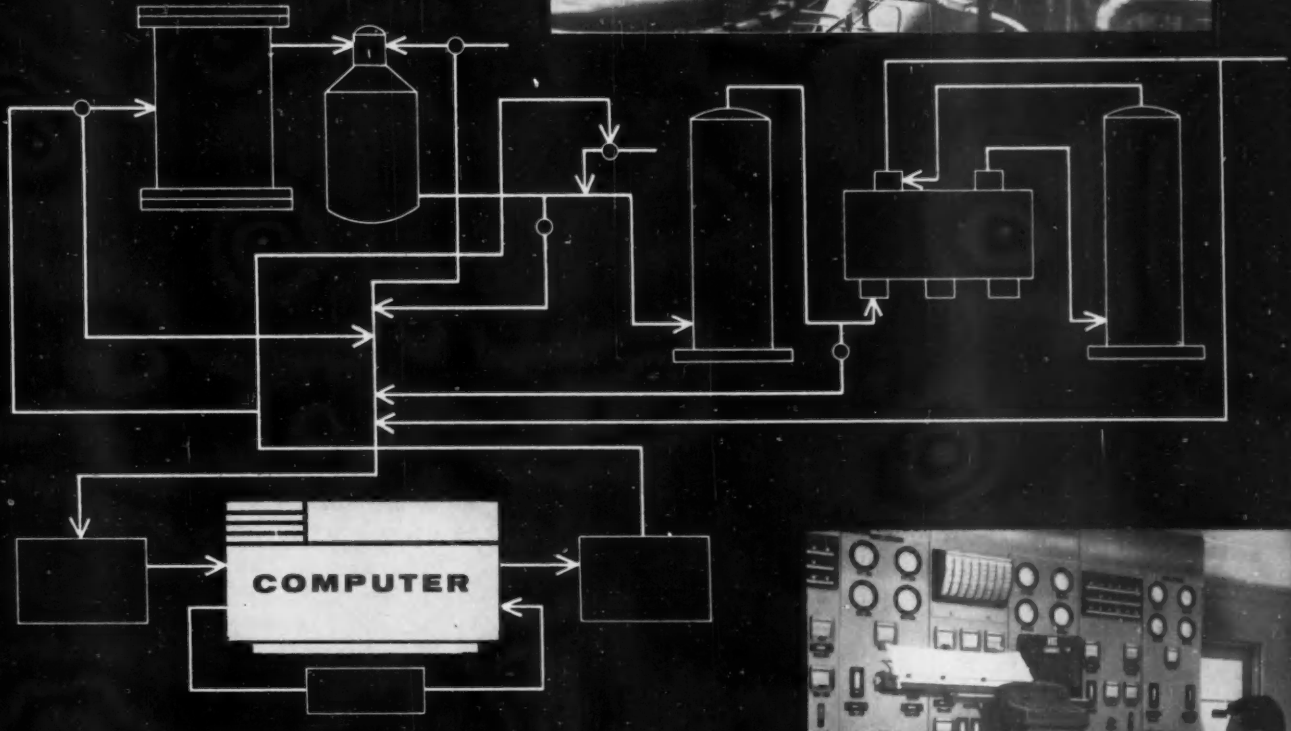
NOVEMBER 1960

Case Study of Computing Control

Monsanto's Ammonia Plant

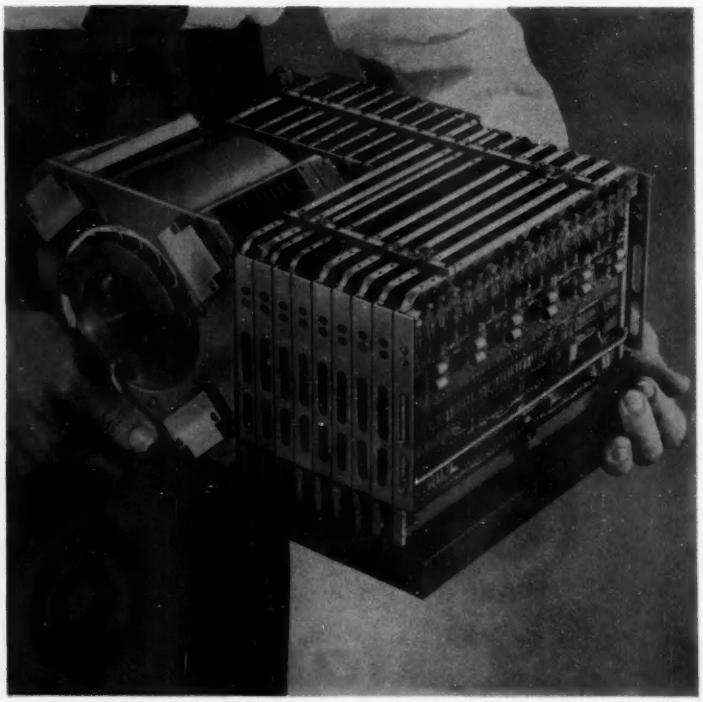




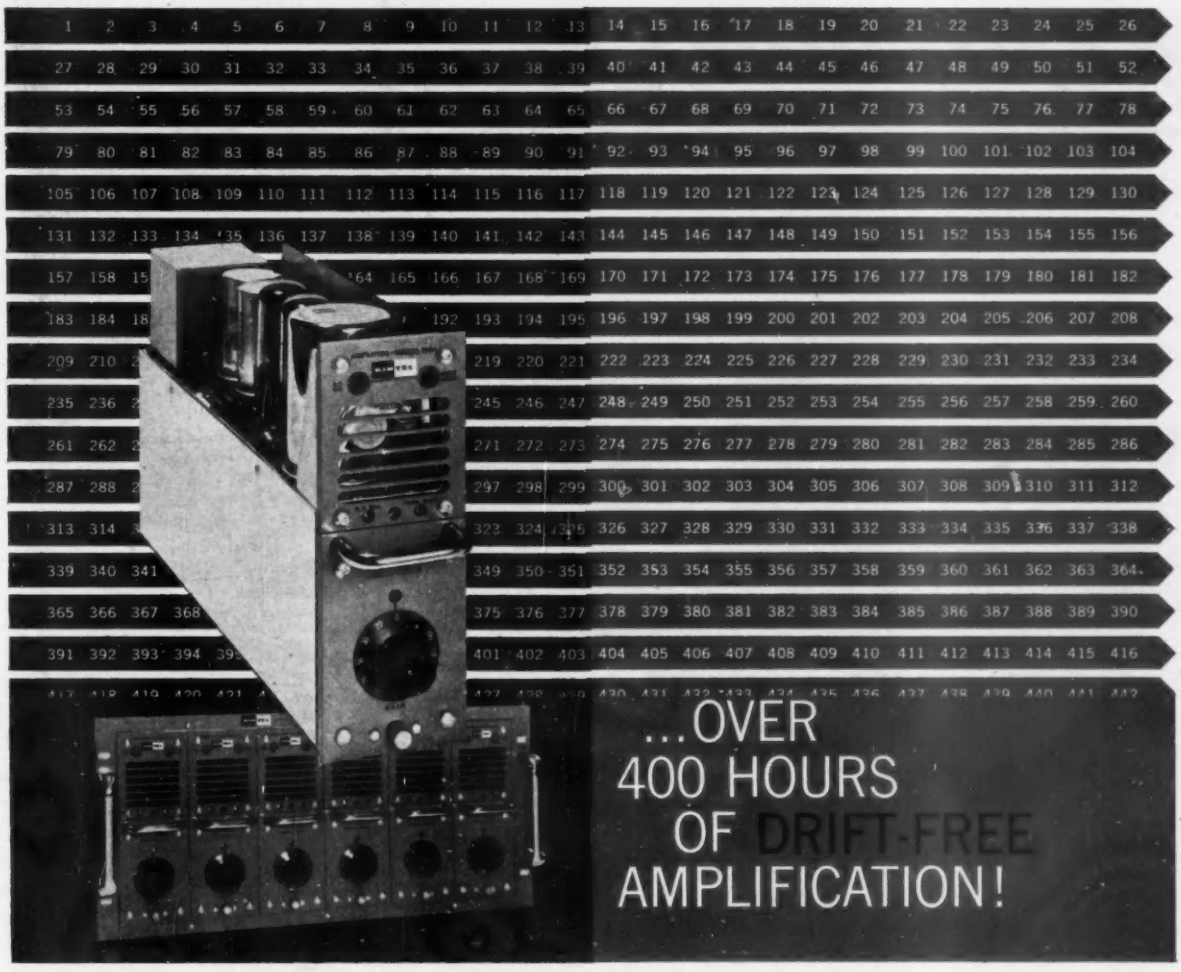
LIBRASCOPE AIRBORNE COMPUTERS

What goes up must fly true. To maintain this condition, Librascope has packaged the rectangular, polar and spherical geometries of flight...in computers easily held in a man's hand or held aloft by an economic expenditure of power...computers unexcelled for 22 years at calculating flight paths, interception courses, fire control trajectories...with answers that come out fast and right. They offer a challenging capability to alert project and design engineers. Write to Librascope, 808 Western Avenue, Glendale, Calif. ■ For engineering career opportunities, address Glen Seltzer, Employment Mgr. Librascope, A Division of General Precision, Inc. ■ For information on

computers that pace man's expanding mind



CIRCLE 225 ON READER SERVICE CARD



Less than 2μv of drift for over 400 hours of continuous operation! That's just one of the many outstanding features of KIN TEL'S new 112A wideband DC amplifier—the unit that is the successor to KIN TEL'S 111 series DC amplifiers. Frequency response is from DC to beyond 40 kc, output capability up to 45 volts. It has an integral power supply, fits the same cabinets and modules, and can be used to replace any KIN TEL Model 111 amplifier.

HIGH ACCURACY. The 112A amplifies microvolt-level signals from DC to 2 kc with a gain accuracy of ±0.5% on any gain setting, better than ±0.01% accuracy on individual gain settings by means of the Micro-Gain adjustment.

RELIABILITY. Overall dissipation has been reduced and reliability enhanced by replacing the tubes used in the 111 amplifier power supply with silicon rectifiers in the 112A. Special heat-conducting shields, heat sinks, and an improved mechanical layout further improve cooling efficiency. Polystyrene capacitors are used in all critical areas. Rugged, militarized components are used wherever compatible with required performance characteristics. Write today for technical information or demonstration.

PRICES:

112A Amplifier with a 112A-A plug-in unit that permits 10 gain steps from 20 to 1000 with 1 to 2 times vernier adjustment at each step... $625

112A Amplifier with a 112A-B plug-in unit that converts the amplifier to a +1 unit having an input impedance over 10,000 megohms, a gain accuracy within ±0.001%... $615

195 Single amplifier cabinet... $125

191A Single amplifer 19″ rack module... $150

190 Six amplifier 19″ rack module... $295

Immediate delivery from stock in reasonable quantities.
Representatives in all major cities.

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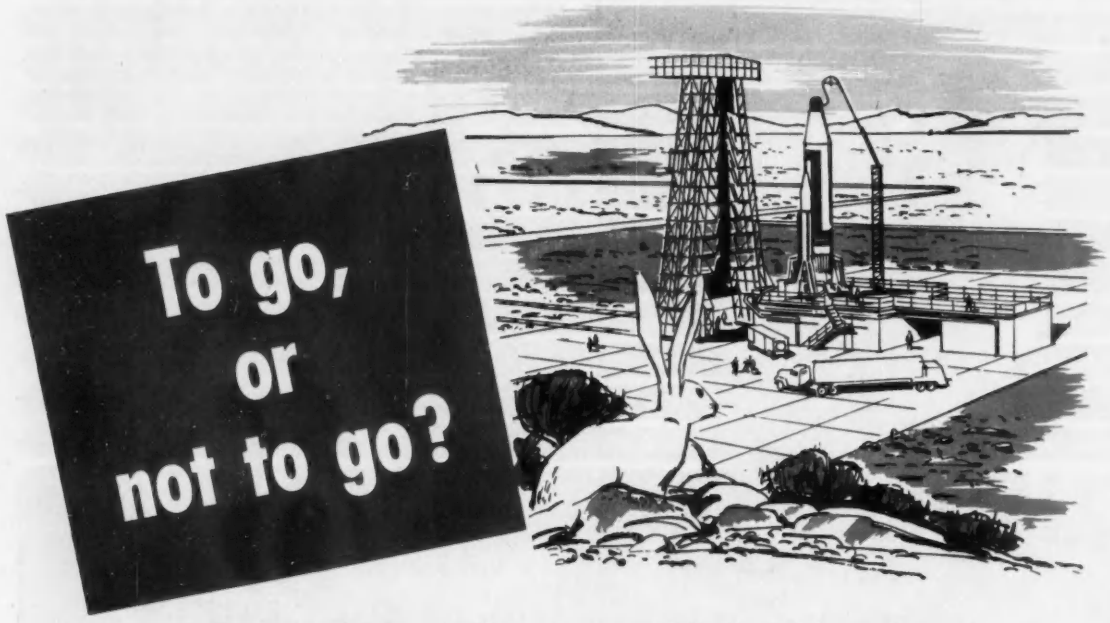
Epsco-West NEWSLETTER



Epsco-West Systems Help Checkout Atlas Missile

Recently Epsco-West put its solid state know-how to work on four identical systems which simultaneously time and monitor the operation of 50 microswitches for operational checkout of the Atlas missile at Vandenburg Air Force Base.

If any of these switches happen to be in a "no go" instead of a "go" condition at the end of a switching sequence, a printer prints out the code number of the faulty circuit.

Epsco-West used solid state circuit elements throughout. Each system contains 250 transistorized plug-in circuit cards. Eight of the 12 logic circuits, comprising 90 percent of the system, are *standard, off-the-shelf* components. Like all Epsco-West systems, those delivered to Convair Division of General Dynamics feature:

* *Reliability* * *Compactness*
* *Low Power Dissipation* * *Low Maintenance*

HOW IT WORKS

Switches are timed by counting 400 cps from a standard power supply on binary coded decimal counters. This establishes a real-time reference for simulating correct switch operation. Continuous comparison of the internally stored program to actual switch operation determines the "go" or "no go" condition.

To make this comparison, individual sensing circuits for each switch determine both the normal and the undesirable switch actuations. If a "no go" condition should exist at the end of the switching sequence (ranging from a few tenths of a second to approximately 3 minutes), a remote comparator and control unit identifies the circuit involved. A printer then prints the code number of the faulty switch circuit.

We would be happy to show you how Epsco-West can produce data control systems faster and with far fewer components. Call your nearby representative, or write for the free new Epsco brochure, "First in Data Control." Write Dept. 21.

5A

Epsco-West
First in Data Control

A Division of EPSCO Inc., Cambridge, Mass.

240 E. Palais Road • Anaheim, California

East of the Mississippi—contact:

MONITOR SYSTEMS INC.

Fort Washington, Pennsylvania

Control ENGINEERING

NOVEMBER 1960
VOL. 7 NO. 11

Published for engineers and technical management men who are responsible for the design, application, and test of instrumentation and automatic control systems

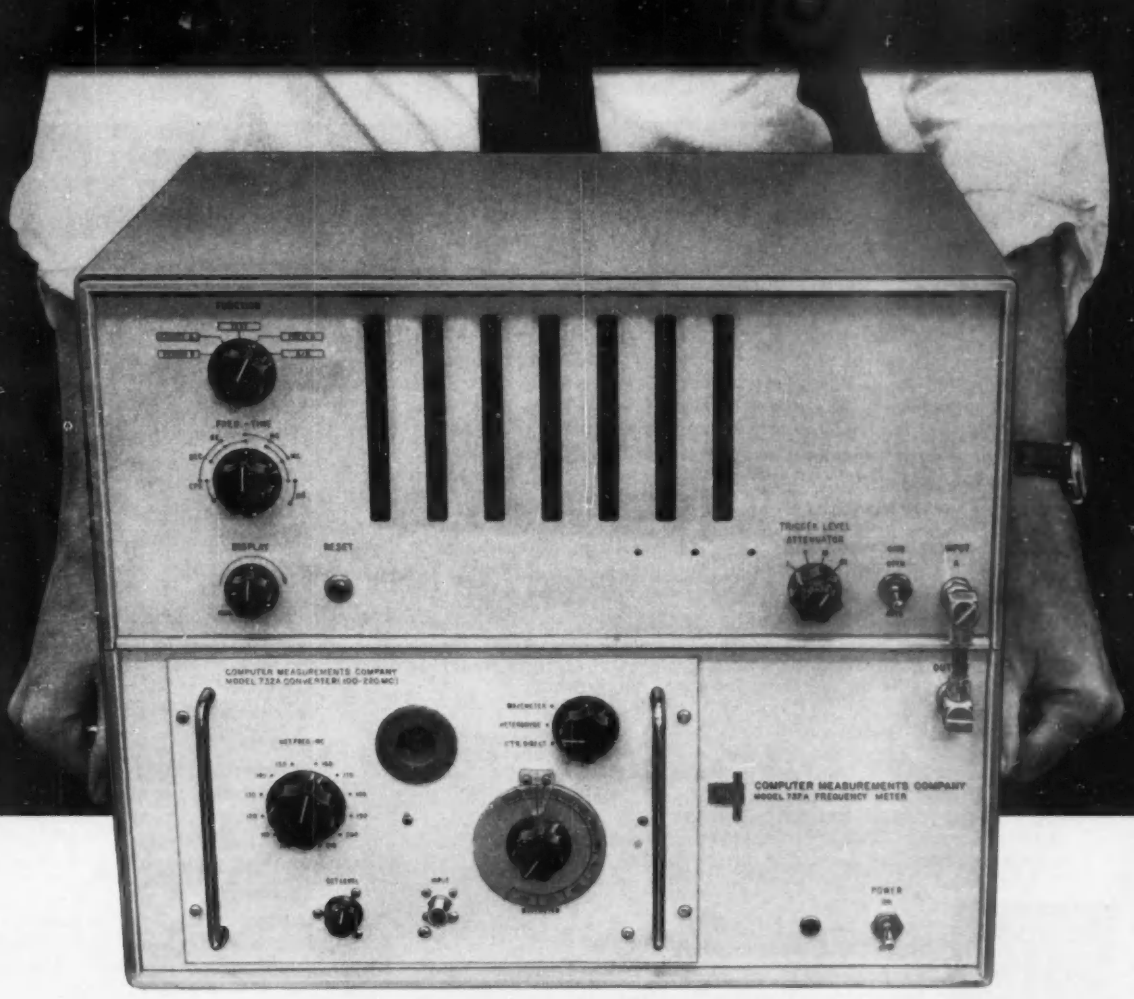
TABLE OF CONTENTS

Continued on next page ➧

IDEAS AT WORK

WHAT'S NEW IN THE CONTROL FIELD

CONTROL ENGINEERING, November 1960, Vol. 7, No. 11. Published monthly by McGraw-Hill Publishing Company, Inc. Executive, editorial, circulation, and advertising offices: 330 West 42nd Street, New York 36, N. Y. Printed in Albany, N. Y.; second class postage paid at Albany, N. Y., and at New York 1, N. Y. U. S. subscription rate for individuals in the field of publication: $5 per year. Further details, p. 6. POSTMASTER: Please send Form 3579 to Fulfillment Manager, Control Engineering, 330 West 42nd Street, New York 36, N. Y.



Model 737A shown with Model 732A Converter Plug-in

→ **Measure frequency dc to 220 mc**

→ **Measure period to 0.1 microsecond**

→ **Measure time interval 0.1 microsecond to 10^7 seconds**

→ **Count dc to 10 mc**

CMC, first with solid state reliability, announces the transistorized Model 737A frequency-period meter.

Here, combined in one compact package weighing a scant 53 pounds, are the functions of a high speed counter, frequency meter, and period meter. Sensibly priced at $2400, the Model 737A mates an all solid state counter with a plug-in vacuum tube heterodyne converter.

Only 14" high, 17" wide, and 13" deep, CMC's new Model 737A requires a mere 125 watts of power which in itself reduces operating temperatures and contributes to long trouble-free life. And except for the vacuum tubes, the new unit is unconditionally guaranteed for two years.

THREE PLUG-INS AVAILABLE

1. 10 mc to 100 mc frequency converter; 2. 100 mc to 220 mc frequency converter; 3. Solid state 0.1 microsecond to 10^7 second time interval section.

Converter plug-ins $250 each. Time interval plug-in $300.

FEATURES AND ADVANTAGES ✱ *Decade count down time base, frequency divider circuits never need adjustment.* ✱ *Automatic decimal point.* ✱ *Nixie readout available as standard option.* ✱ *Stability, 2 parts in 10^7 standard, 5 parts in 10^8 special.* ✱ *Accuracy, ±1 count ± oscillator stability.* ✱ *Sensitivity, 0.25 v rms.* ✱ *Standardize against WWV.* ✱ *Remote programming without special regard to cable length, type of cable, or impedance matching.* ✱ *Printer output to drive digital recording equipment, punches, inline readout and other data handling gear, $80 extra.*

NEW TECHNICAL BULLETIN TELLS ALL

Your nearby CMC engineering representative will be happy to provide you with full technical, sales, and delivery information and arrange a demonstration at your convenience. For a free copy of our new technical bulletin, please address Dept. 21.

CMC 36

Computer Measurements Co.

A Division of Pacific Industries

12970 Bradley Avenue, Sylmar, California

Phone: EMpire 7-2161

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Control ENGINEERING

NOVEMBER 1960 VOL. 7 NO. 11

Published for engineers and technical management men responsible for the design, application, and test of automatic control systems

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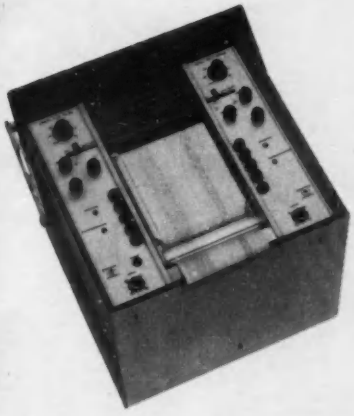
keep an accurate graphic record

OF RESEARCH, DESIGN, TEST DATA

two channels



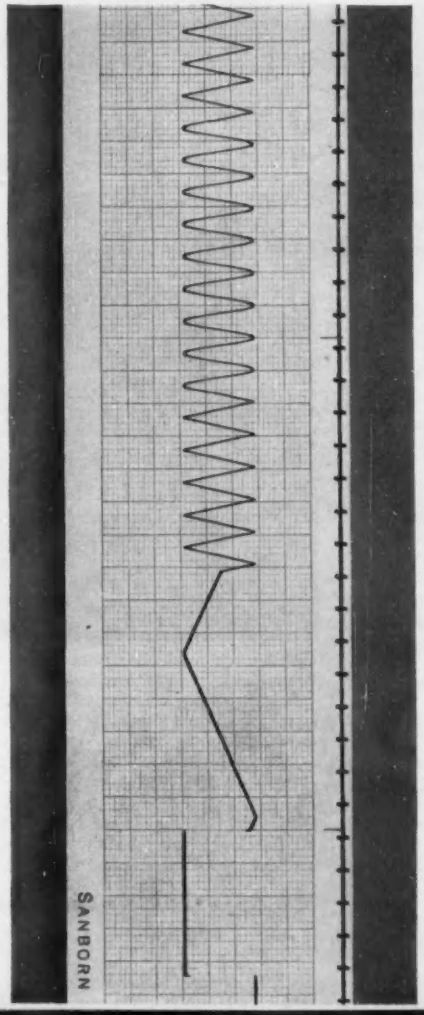
For General Purpose DC Recording — Model 320

For recording *two variables* simultaneously, the Model 320 provides a versatile, transistorized amplifier for each input signal. The rugged 2-channel recorder assembly has heated stylus recording on two *50 mm wide* rectangular coordinate channels, 4 pushbutton chart speeds, and 6 inches of visible chart. The Recorder can be placed vertically, horizontally or at a 20° angle.

MODEL 320 SPECIFICATIONS

Sensitivity: 0.5, 1, 2, 5, 10, 20 mv/mm and v/cm
Frequency Response: 3 db down at 125 cps, 10 mm peak-to-peak
Common Mode Voltage: ±500 volts max.
Common Mode Rejection: 140 db min. DC
Calibration: 10 mv internal ±1%
Output Connectors for each channel accept external monitoring 'scope or meter
Price: $1495

NEW SANBORN PORTABLE DIRECT WRITING RECORDERS FOR IN-PLANT, LABORATORY OR FIELD RECORDING



Two models of this 21 lb. brief case size recorder are available — Model 301 for AC strain gage recording, Model 299 for general purpose DC recording. Both provide immediately visible, inkless traces by heated stylus on 40 division rectangular coordinate charts . . . frequency response to 100 cps . . . 5 and 50 mm/sec chart speeds . . . approx. 4 inches of record visible in top panel window.

single channel

MODEL 301 SPECIFICATIONS

The amplifier section of the Model 301 is an all-transistorized carrier type with phase sensitive demodulator. The power supply and internal oscillator circuits are also transistorized.
Sensitivity: 10 uv rms/div (from transducer)
Attenuator Ratios: 2, 5, 10, 20, 50, 100, 200
Carrier Frequency: 2400 cps internal
Transducer Impedance: 100 ohms min.
Calibration: 40 uv/volt of excitation
Output Connector: for external monitoring 'scope or meter
Price: $750

MODEL 299 SPECIFICATIONS

Combines the dependability of transistors with the high input impedance of vacuum tubes for reliable broad-band DC recording.
Sensitivity: 10, 20, 50, 100, 200, 500 mv/div and 1, 2, 5 and 10 v/div
Input Resistance: 5 megohms balanced each side to ground
Common Mode Voltage: ±2.5 volts max. at 10 mv/div sensitivity increasing to ±500 volts max. at other sensitivities
Common Mode Rejection: 50:1 most sensitive range
Calibration: 0.2 volt internal ±1%
Output Connector: for external monitoring 'scope or meter
Price: Model 299 (with zero suppression) $700
Model 299A (without zero suppression) $650

All prices are F. O. B. Waltham, Mass., within continental U. S. A. and are subject to change without notice.

Contact your Sanborn Sales-Engineering representative for complete information, or write the main office in Waltham. Sales-Engineering representatives are located in principal cities throughout the United States, Canada and foreign countries.

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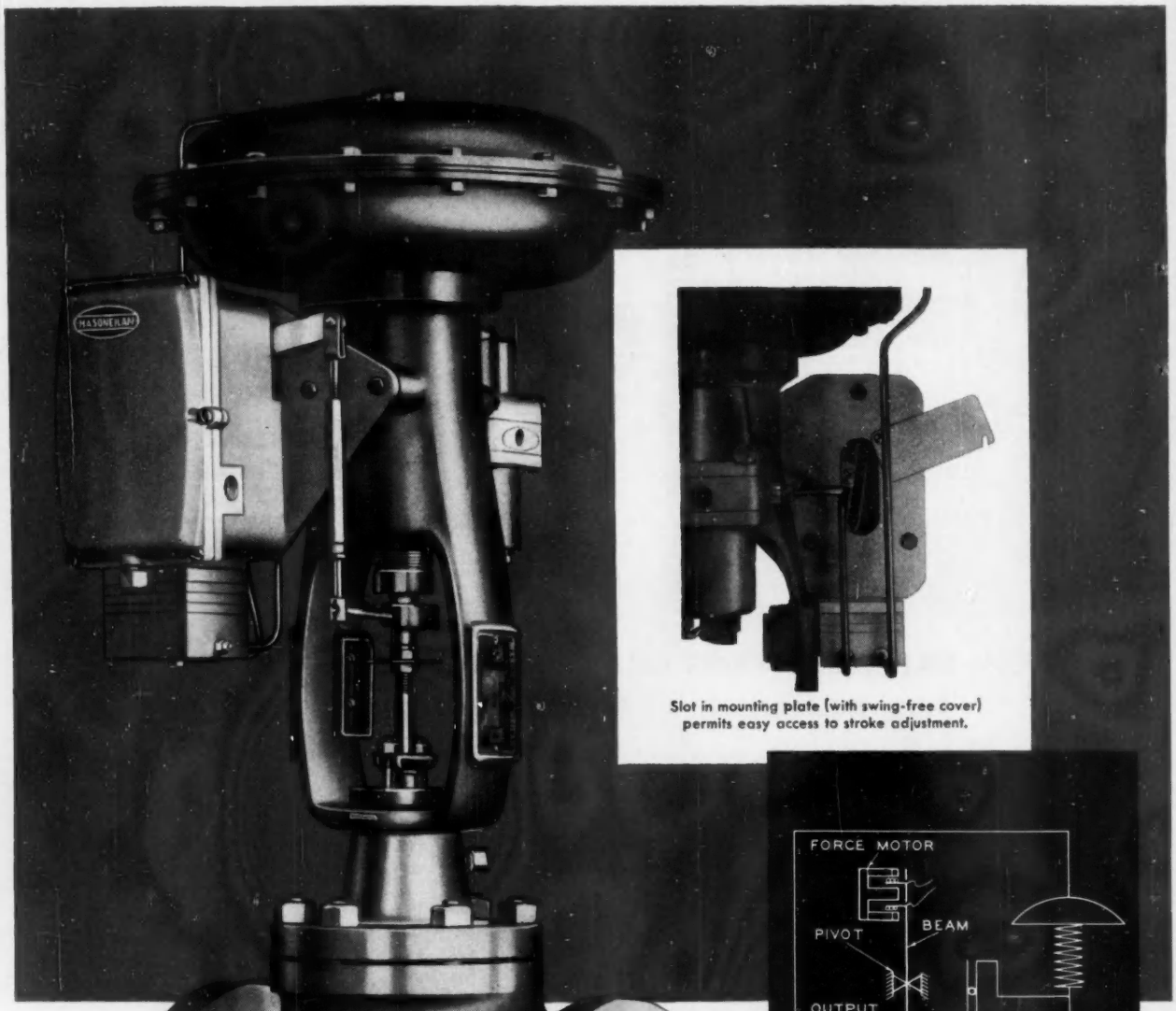
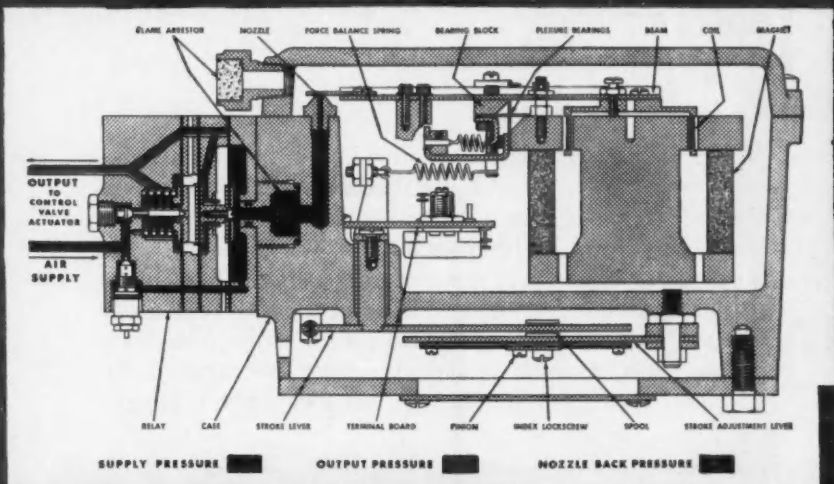


Slot in mounting plate (with swing-free cover) permits easy access to stroke adjustment.

Diagrammatic of operation.

Model 8010 mounted on spring-diaphragm actuator. Note compact design.

Schematic of air circuits.



Speed The speed of the positioner, with integral volume and normal 20 psi supply pressure, is tabulated below.

ACTUATOR SIZE	VALVE STROKE (inches)	
9	½	
	¾	1.8
11	1	2.8
	1½	3.3
13	1	4.9
	1½	6.3
15	1½	9.4
	2	11.4
18	2½	21
	3½	29
	4	32

Performance Data

Open-loop Gain* — approximately 100

Linearity — within ±1% of full stroke

Repeatability — within 0.2%

Load Sensitivity — Output pressure change of 1.2 psi per 0.1% of full stroke offset

Supply Pressure Effect — ±1% of full stroke for ±5 psi change from 20 psi

Now! Masoneilan Electropneumatic Positioner with Velocity Feedback

Combines high open-loop gain and closed-loop stability to give you Precise Positioning and Superior Dynamic Response

The new Masoneilan Model 8010 Electropneumatic Positioner offers optimum performance plus these design advantages:

- A true positioner — *direct* comparison of valve stem position with controller output signal provides dynamic response and positioning accuracy not obtainable with transducer and pneumatic positioner combination.
- Electrical circuit easily adapted to a variety of controller output signals.
- Extra large stabilized magnet, plus efficient magnetic circuit, provides high force changes.
- Explosion-proof construction meets requirements of Class I, Division I, Group D.
- External stroke adjustment accessible without removal of cover — no exposure of electric wiring.
- High capacity relay for fast stroking speeds. Relay may be mounted in any one of four positions to facilitate piping.
- Balanced beam permits installation of valve in any position without shift in calibration.
- Available for 3-15 psi or 6-30 psi valve spring ranges and for split-ranging. Standard stroke ranges ⅜"–3" and 2"–4". Others available.
- Available with direct or reverse action and for direct or reverse actuators.

You can now utilize the desirable characteristics of electronic control and obtain the power and smooth throttling action of pneumatic valves by using Masoneilan Electropneumatic Positioners. Full details on request. Ask a Mason-Neilan representative or write direct —

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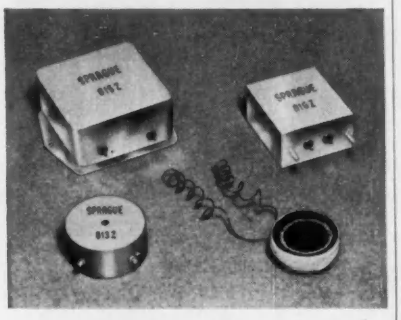
MNO-19

New Line of Precision Toroidal Inductors For Practically Every Application



Designed for use in commercial, industrial, and military apparatus, Sprague Precision Toroidal Inductors are customarily supplied to the close inductance tolerance of ±1%. The broad line of Sprague inductors includes such styles as open coil, plastic-dipped, rigid encapsulated types with tapped or through-hole mounting, and hermetically-sealed inductors.

All styles, with the exception of the open-coil type, meet the requirements of Specification MIL-T-27A.

Several core permeabilities may be obtained in each of the five basic sizes of Sprague inductors to give the circuit designer the optimum selection of desired Q and current carrying abilities. Each of the core sizes is available with several degrees of stabilization. Inductors made with cores which have not been subjected to the stabilization process exhibit low inductance drift with time and have a low temperature coefficient of inductance. Where a greater degree of permanence of characteristics is required, cores with two different stabilization treatments can be used for most types of inductors.

Sprague toroidal inductors may be operated from −55C to +125C. Temperature cycling of finished inductors is a standard production procedure in order to equalize internal stresses and insure permanence of electrical characteristics.

For detailed information on Sprague Precision Toroidal Inductors, write on company letterhead for portfolio of engineering data sheets to Technical Literature Section, Sprague Electric Company, 407 Marshall Street, North Adams, Massachusetts.

SHOPTALK

New consulting editor

We're glad to welcome Dr. Theodore J. Williams, engineering supervisor, Research & Engineering Div., Monsanto Chemical Co., to CONTROL ENGINEERING's consulting editor ranks. Ted replaces John Johnston and will give aid and counsel in our coverage of the process control field. In many ways this is a "Williams" issue: Ted is the Control Personality of the month (see page 27) and co-author of the case study of Monsanto's computing-control system (see page 103). Our thanks go to Jack Johnston for his four years of service.

First full report of process computing-control

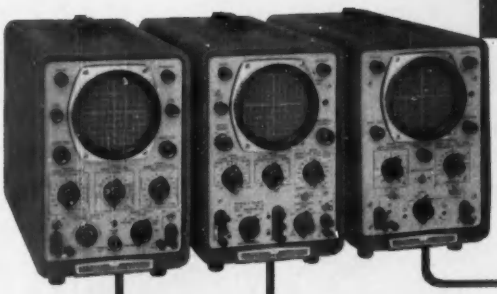
Since our early editorial coverage of the why and how of on-line computer control of flow processes in the June and September 1957 issues of CONTROL ENGINEERING, the editors have been anxiously awaiting the day when they could report the details of a major on-line installation. The time has arrived with the 12-page case study of Monsanto's ammonia plant "Closed Loop Computing-Control at Luling" on page 103 of this issue. Major working responsibility for the project fell on the shoulders of the co-authors, Ted Williams representing the engineering department of Monsanto's Research and Engineering Div. and Robert D. Eisenhardt, Jr. representing Monsanto's Inorganic Chemicals Div. as supervisor, special instrumentation. Ted supplied the systems engineering philosophy, while Bob (photo) contributed a solid background in control instrumentation through experience at Bailey Meter Co. and Mallinckrodt Chemical Works following a BS in EE degree from Drexel Institute. Don't miss this opportunity to follow the system from conception to operating results.

Editor turns TV producer

You never know what you're going to get into when you become a magazine editor. Last month, for example, Chief Editor Bill Vannah suddenly found himself acting as a TV producer, helping Betty Adams of WBZ TV, Boston put together a one-half hour show for her Sunday morning program "Dimensions". The idea was to demonstrate and discuss the impact of automatic systems on industry. Bill did this by filming a computer controlled ice cream mixing process, a numerically controlled machine tool in action, and the Fluid Power Control Lab. at MIT, while moderating the show with a discussion of the types of engineers required to do control engineering work and the impact of these systems on the public and labor in general. What's next?

Call your hp rep today for a demonstration of one of these

3 POPULAR hp OSCILLOSCOPES



Production or lab instruments—Simple to use, even for non-technical personnel—Moderately priced—Full 10 cm x 10 cm display—Automatic calibration waveforms—Low phase shift—Automatic triggering for optimum presentation—"Times-5" sweep expander magnifies trace, improves resolution.

DC to 200 KC

Models 120A/AR combine minimum controls with ϕ automatic triggering for utmost speed, convenience. Horizontal amplifier dc to 200 KC; phase shift only ± 2° to 100 KC. More X-axis information due to horizontal amplifier sensitivity control, with vernier, 5% accuracy. Balanced input on most sensitive ranges for low level work. Times-5 sweep expander, all ranges. 15 calibrated sweep speeds, 5 μsec/cm to 0.2 sec/cm. Vernier, expander extend speed range 1 μsec/cm to 0.5 sec/cm. 10 mv/cm sensitivity calibrated vertical amplifier, drift-free trace. ϕ 120A (cabinet) or ϕ 120AR (rack), $435.

DC to 200 KC – DUAL TRACE

Models 122A/AR provide simultaneous two-phenomena presentation, are ideal for direct comparison of filter, amplifier output/input phenomena; vibration testing. Unique ϕ front-panel automatic calibrator waveform switch. Twin vertical amplifiers operate independently, simultaneously, differentially. Automatic triggering, automatic synchronization, single trace operation when desired. Sensitivity 10 mv/cm to 100 v/cm, 15 calibrated sweeps, vernier extension. Horizontal amplifier dc to 200 KC. ϕ 122A (cabinet) or 122AR (rack), $625.

DC to 300 KC – "BIG SCOPE" PERFORMANCE

Models 130B/BR provide wide usefulness, simple operation and rugged dependability. 21 calibrated sweep times, 1 μsec/cm to 5 sec/cm. Vernier, expander extend range 0.2 μsec/cm to 12.5 sec/cm. Twin horizontal and vertical amplifiers, phase shift ± 1° to 50 KC; sensitivity 1 mv/cm to 125 v/cm. Balanced input on 6 most sensitive ranges. Common mode rejection 40 db. Stability 1 mv/hour after warmup. Triggering automatic, internally, line power, externally, 0.5 v or greater. ϕ 130B (cabinet) or 130BR (rack), $650.

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Thirteen precision ϕ oscilloscopes, dc to 1,000 MC

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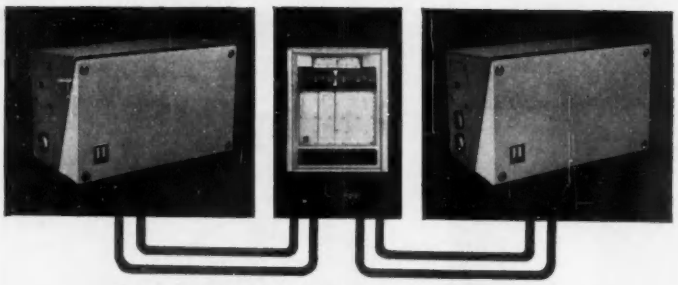
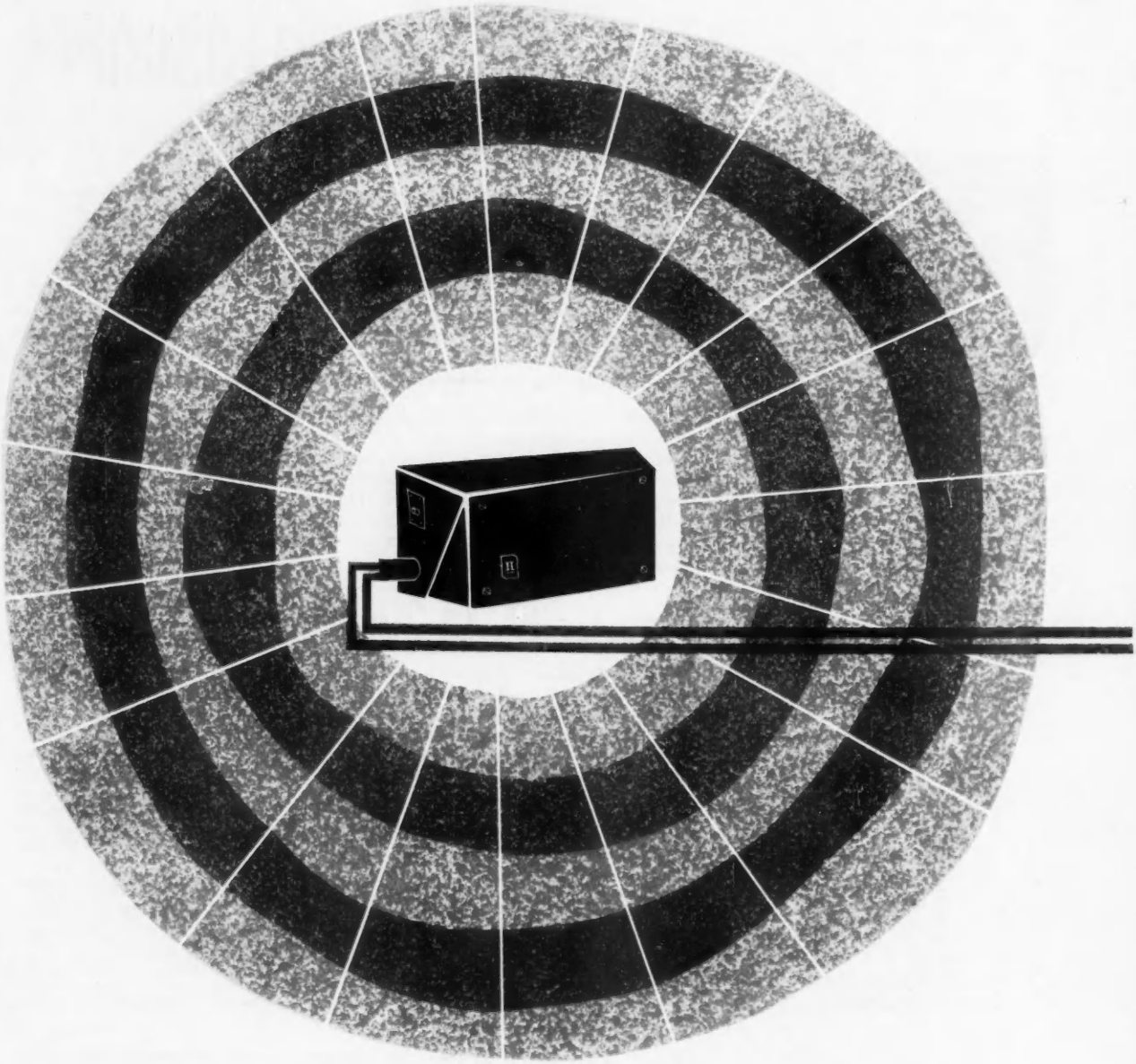


***ElectriK Tel-O-Set*—the true 2-wire system**



TAKING THE HEAT OFF FIELD-MOUNTED TRANSMITTERS

The *ElectriK Tel-O-Set* System takes the heat off field-mounted instruments by *eliminating heat-generating tubes and power packs.* There's no external power required at any *Tel-O-Set* field-mounted instrument. The line power connection is made only at the receiver.

Tel-O-Set field-mounted instruments operate on a low calorie diet of 4-20 milliamps . . . less than 0.6 watts. A simple two-wire line connects the field-mounted instruments with the control room. The two wires carry the control signal as well as the power. The d-c transmission avoids stray pickup and phasing problems . . . eliminates the need for shielding the line.

The 4-20 milliamp signal range of the system gives a live zero and permits the use of the most reliable transistors available. These d-c signals can be fed into data handling systems and millivolt-actuated instruments . . . can be easily transduced to a standard 3-15 psi pneumatic signal to operate existing pneumatic systems.

The basic circuit used in *Tel-O-Set* transmitters, receivers, controllers and other instruments has been thoroughly proved in thousands of applications in the last five years. This circuit uses a force-balance feedback system to increase the accuracy and the dynamic response of the system by decreasing hysteresis effects and sensitivity to changes in ambient conditions.

Take a new look at your control applications with the *ElectriK Tel-O-Set* System in mind! Get complete technical data from your local Honeywell field engineer. Call him today . . . he's as near as your phone. MINNEAPOLIS-HONEYWELL, 21 Penn Street, Fall River, Mass.

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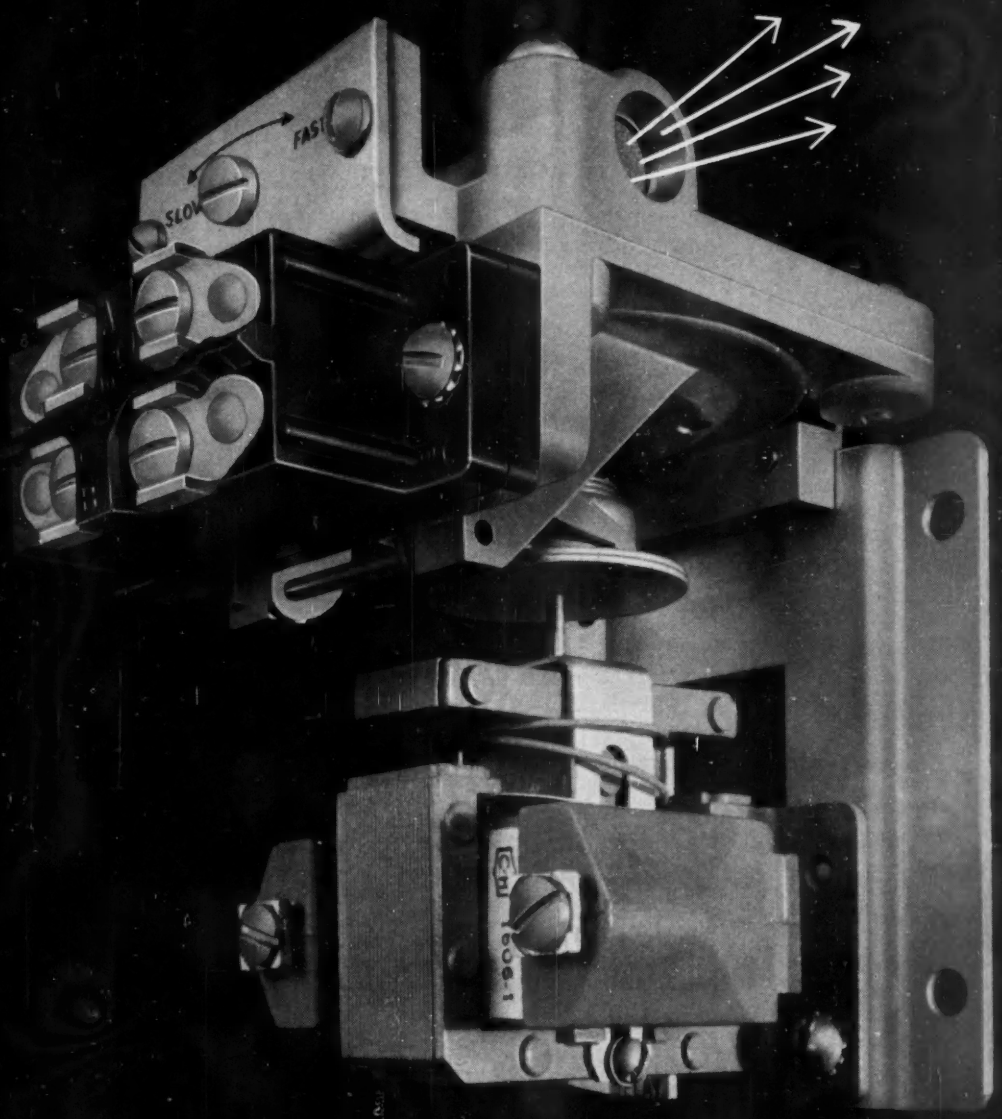
NO CHECK VALVE! Air cleans filter as it exhausts through the vent. No check valve to clog and cause trouble.



EXPLODED VIEW SHOWS HOW NEW DIAPHRAGM DESIGN ELIMINATES CHECK VALVE

New! A Cutler-Hammer one-minute pneumatic timer that eliminates the troublesome check valve!

Unique diaphragm design makes timer more accurate and dependable than any other

The new Cutler-Hammer one-minute Pneumatic Timer, by eliminating the conventional check valve, does away with failures caused by dust.

Using a silicone diaphragm, this timer pulls fresh air in through a filtered vent, and on the exhaust stroke blows away any dust that may have collected on the surface of the filter. No chance for dust to affect accurate timing or make the timer inoperable. The silicone diaphragm works equally well 150°F above zero or 45°F below zero.

No other timer is more accurate. It adjusts easily from .2 seconds to 60 seconds with a 7½-turn screw that provides precise adjustment to the desired time setting. All you need is a screwdriver. And, it can be changed from "on delay" to "off delay" in seconds. Smallest electrical dimensions of any one-minute timer, too. Call your Cutler-Hammer distributor for full details or send for Publication L071-W227.

What's new at Cutler-Hammer?

You can see the big change at Cutler-Hammer wherever you look. New, better products. New, expanded engineering staff and facilities. New added plant capacities. All done to help you meet the big opportunities of this decade.

If you're planning ahead, we'd like to show you how our talents and experience in electrical control could help you. Contact the nearest Cutler-Hammer sales office.

WHAT'S NEW? ASK...

CUTLER-HAMMER

Cutler-Hammer Inc., Milwaukee, Wisconsin • Division: Airborne Instruments Laboratory • Subsidiary: Cutler-Hammer International, C. A. Associates: Canadian Cutler-Hammer, Ltd.; Cutler-Hammer Mexicana, S. A.

FEEDBACK

This reader built an automatic digital weather data system after he tired of changing charts and winding clocks.

In a Down East Shack

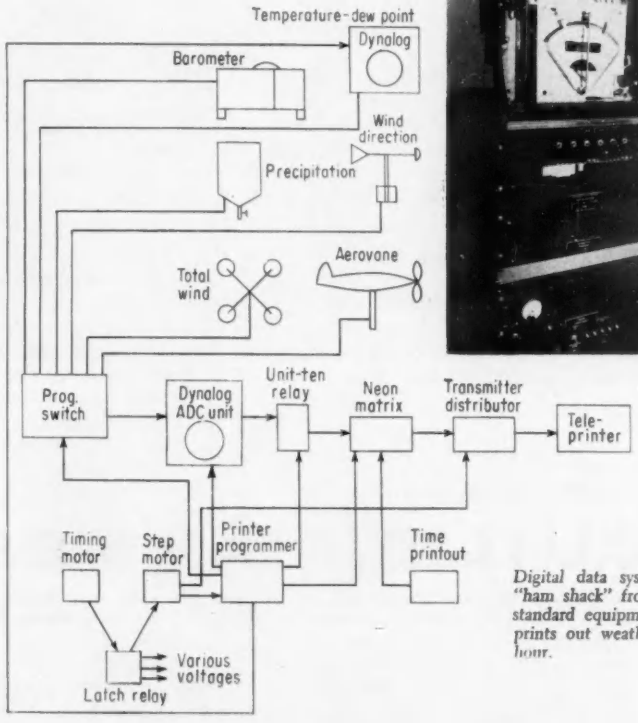
TO THE EDITOR—

Many people have "mental blocks" over data systems. They think that such systems are terribly complicated and costly. Actually, in any data system one is only repeating a few functions many times—adding to the circuitry but not to the complexity. Because I am experienced in process control instrumentation and have long worked in my home shop with barographs, thermographs, and wind recorders, I decided last winter to combine my profession and hobby and build a digital weather data system. My successful construction of a system from standard parts, just because I wanted to, demonstrates that data systems aren't so hard to understand after all. Construction took 50 hours.

The system was designed to monitor and print out the readings of one set of standard weather instruments operated in my home. Clock winding and chart changing had become a nuisance. The block diagram shows the system elements. Temperature, pressure, dew point, wind direction, wind speed, total wind, total precipitation at the end of each hour, time, calibration, and station designation are all printed out in digital groups on a standard teleprinter continuously or on the hour.

Limitations:

- It takes 2.5 min to print out one set of readings.
- Pressure is printed to two digits; therefore reference of printed value to a curve in order to get actual pressure is necessary.
- Zeroes of temperature and dew point measurements must be shifted as seasons change to take care of the fact that minus signs are not available.
- Time reads out to two digits, which is satisfactory because system reads out



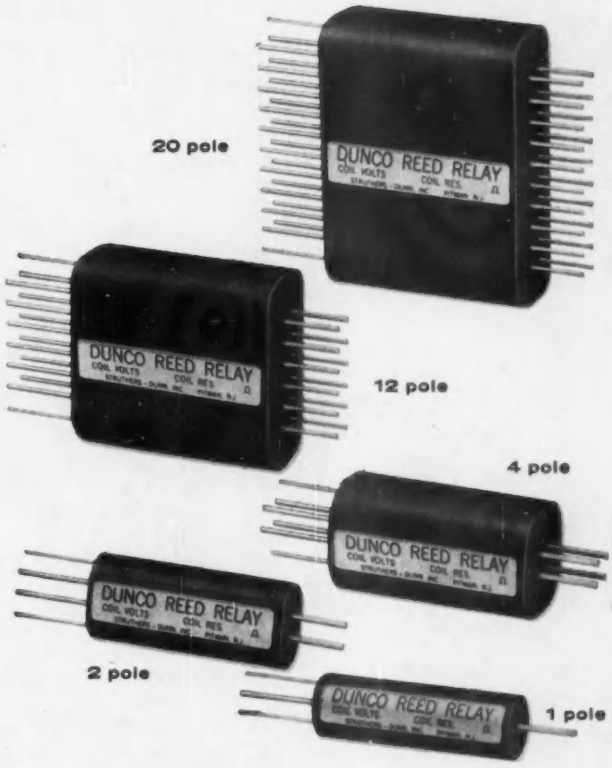
Digital data system built in "ham shack" from modified standard equipment gathers and prints out weather data every hour.

New!

Standard line of

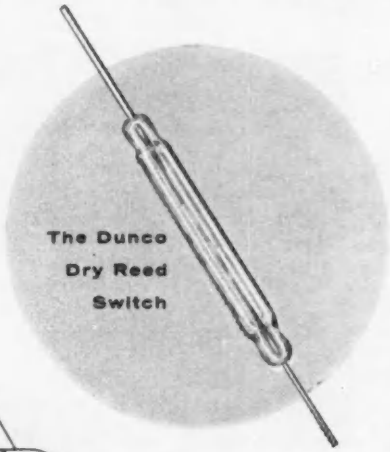
Dunco

DRY REED RELAYS



- *Encapsulated units provide practically any combination of normally-open (Form A) and normally-closed (Form B) contact arrangements.*
- *Mount in any position.*
- *Contacts completely unaffected by atmospheric contamination.*
- *BREAK-MAKE ACTION can be furnished to insure non-overlapping of contact closures.*
- *Multi-coil arrangements for logic elements available.*

Write for Dunco Reed Relay Bulletin.



DUNCO DRY REED RELAYS provide economical and exceptionally fast low level and light load switching for computer and data handling applications. Life is on the order of hundreds of million operations. From one to 20 switches with surrounding magnetizing coil are encapsulated to form a relay unit. The Dry Reed Switch is rated 15 watts for resistance loads at maximums of 250 volts or 1 ampere; 50 milliohms maximum contact resistance; 500 V. a-c minimum breakdown voltage; and 500,000 megohms minimum insulation resistance.

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FEEDBACK

exactly on the hour.

System construction and operation

The input measuring instrument is a standard Foxboro EMF Dynalog modified by replacing the pen mechanism, chart drive, and chart plate with a Wallace and Tiernan analog to digital converter from a surplus Navy automatic weather station. The converter has 10 "tens" segments and 100 "ones" pins arranged in an arc. A pointer connected to the Dynalog output shaft swings over the arc until pulled by a clamping bar into contact with the segment and one pin during the readout cycle. A 10-pole, double throw crossbar switch connects the converter and a matrix that translates the 0 to 9 converter output to the binary code of the teleprinter.

When the pointer clamps for a readout, the tens segment is read into the matrix and through the transmitter distributor to the printer. After this cycle the crossbar switch flops and allows the unit pin to read into the matrix, through the transmitter distributor, and to the printer. The result is two digits: 01, 04, 25, etc.

After this cycle has occurred, the next measured input is switched into the Dynalog and the procedure repeated. Between groups of digits, a space pulse and figures shift is programmed into the printer.

Matrix

This is the heart of the system. It consists of a neon (NE-2 neon lamps) matrix and five Kurman sensitive relays. It has 10 input lines for the digits from the analog to digital converter plus additional lines for space, line feed, carriage return, and figures shift signals.

Transmitter distributor

The transmitter distributor is a standard piece of communications equipment consisting of a synchronous motor, a set of contacts, and an electromagnetic clutch. It converts the Kurman relay closures to pulses and distributes them, along with start-stop pulses, to the teleprinter.

Printer programmer

A 50-point self-homing stepper, it:
- provides the impulses that operate the information programmer, to present the information from each weather instrument in sequence
- provides the pulse that operates the Dynalog clamping bar
- provides the pulse that operates the

Photo Courtesy of
Consolidated Electrodynamics Corporation

An Integral Part of Your Equipment
This high-vacuum pump incorporates three Variacs for the control of motor speed and voltages.

A Research Tool
Variacs control current through coils used for heating ingot of experimental semiconductor material.

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. . . featuring DURATRAK,* G-R's exclusive treatment for the Variac contact surface.

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Engineer uses a Metered Variac to check voltage range specifications of a prototype electronic instrument.

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CIRCLE 19 ON READER SERVICE CARD

FEEDBACK

crossbar relay
- provides a homing bank for the entire system
- triggers a time-delay that counts miles of wind
- switches the temperature-dewpoint instrument from one variable to the other.

Temperature-Dewpoint: A Giannini Microtorque potentiometer connected across a 6-volt battery is linked to the output shaft of a Foxboro resistance Dynalog that is switched alternately from a standard resistance bulb to a Dewcell.

Wind: Wind speed is read into the system in two ways: first, from the actual output of an Aerovane through a dropping network, in mph (0 to 99); second, from the 1/60th mile contacts of a Navy three-cup anemometer into a stepping switch.

Pressure: A Friez Micro-barograph is fitted with a Microtorque potentiometer. Work is underway to present the reading in three digits.

Precipitation: Presently this comes from a tipping bucket gage. The tilts of the bucket operate a 100-tooth stepping unit, whose shaft is geared to a potentiometer. This is calibrated in terms of rainfall and can be read to 0.02 in. (bucket tips for each 0.2 in.). The potentiometer can as easily be connected to a weighting-type gage, which was not at hand here.

Wind Direction: Presently this is read into the system from a vane having a 360-deg potentiometer in it. This reads out 0 to 36.

Station Designator: For lack of something better, this has been designated as "01". It occurs as the first group of a sequence and is read in by applying a voltage directly to the matrix from the printer programmer.

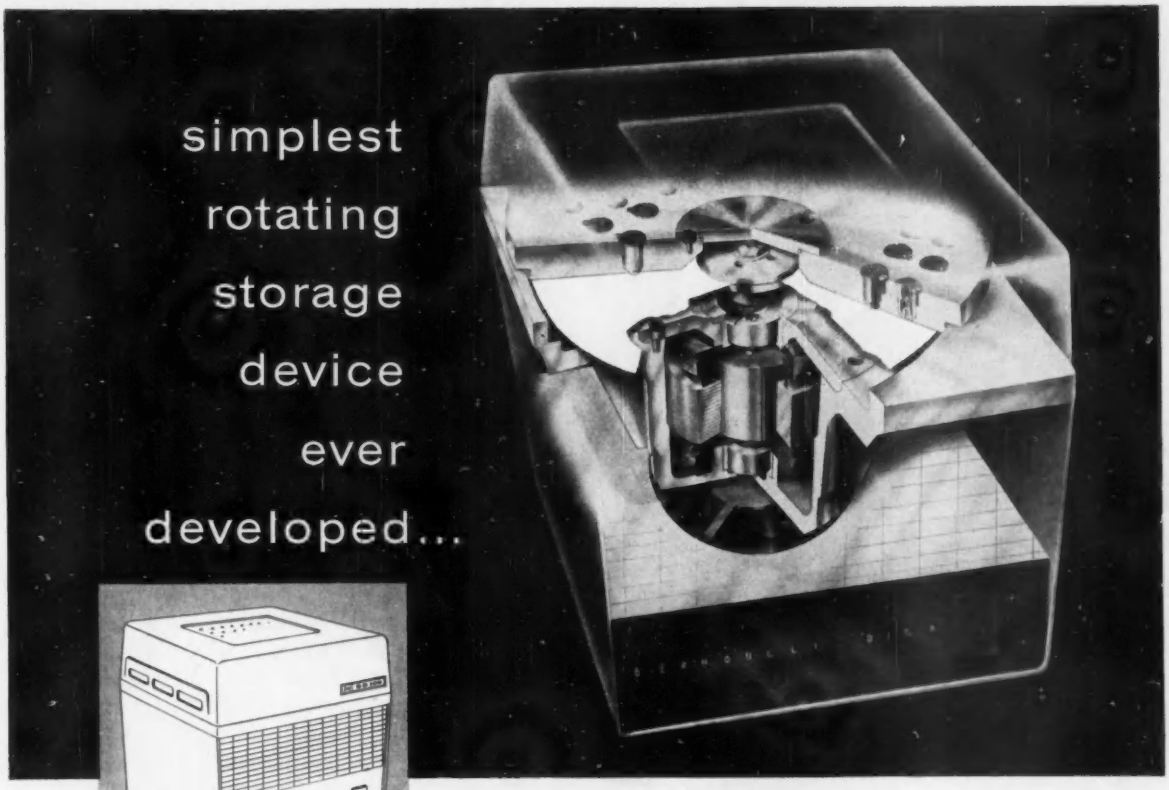
Calibration: Presently this reads out as 85. This is a fixed voltage read into the analog to digital converter and serves as an indication of any voltage drifts or changes in calibration.

Time: This is programmed in through a 24-point rotary selector switch, which rotates one contact each hour. This output goes to the matrix, and is read out as 00, 01, 02, etc.

Date: This might be useful, but would add complications to the system. Since each 24-hr run can be torn off the printer and stamped, date is not of great importance to this particular system.

N. K. Thompson, W1LWV
Instrument Supervisor
Great Northern Paper Co.
Millinocket, Me.

simplest rotating storage device ever developed...



The Bernoulli Magnetic Disk Memory, a proprietary development of The LFE Applied Research Laboratory, is now available in prototype or production quantities.

The first models, designated as the BD-100 Series, are ideally applicable for use in general purpose EDP Systems. In addition, because of each unit's small size and weight, and ability to withstand severe environmental conditions, the BD-100 Series is also applicable to a wide variety of fixed station and mobile digital computers. For a complete description write for Technical Data Digest No. 607C.

SPECIFICATIONS BD-100 SERIES

Storage Capacity (Max) Bits	100,000
Bits Per Track (Max)	3,000
Bit Rate — kc	90-400
Track Layout As Required Typical:	
Total Tracks	40
Data Storage Tracks	32
Spare Tracks	3
Clock and Timing Tracks	3
Register Tracks	2
Number of Registers	4
Register Length — Bits	32
Register Adjustment — Bits	±3
Disk Speed — RPM Induction or Synchronous Motors Available	1800-8000
Power Source — cps	60-400
Magnetic Heads (Compatible with solid state circuits) Typical: (For 200 kc Operation)	
Inductance (Per Leg. — C.T. Coil) — uh	55
Write Current (P/P Manchester) — ma	250
Read Out (Min. P/P Full Coil) — mv	20
Size — Inches (Less Electronics)	9 x 9 x 5
Wide variations from typical specifications can be made to meet customer's requirements.	

LFE
Data Storage Operations
COMPUTER PRODUCTS

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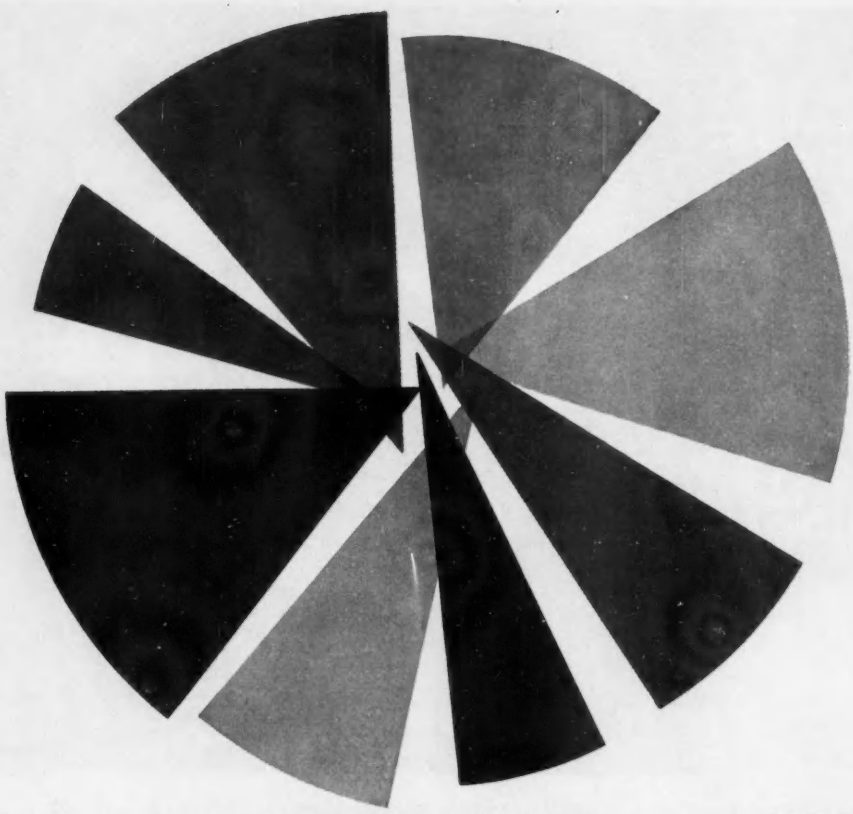
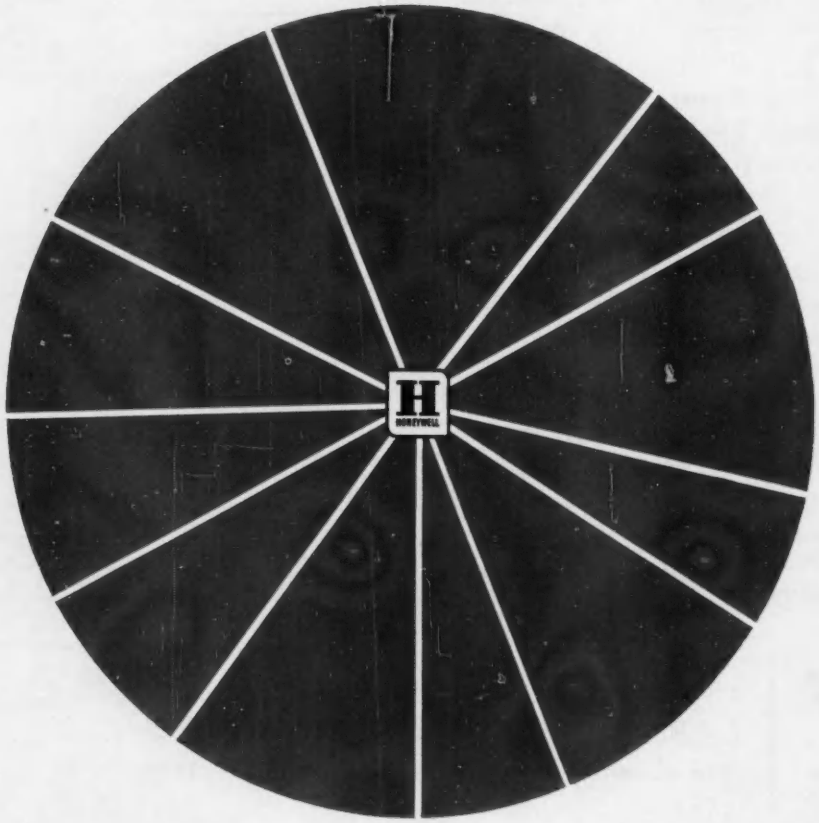
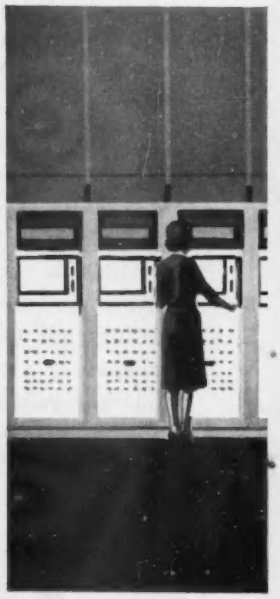
CIRCLE 21 ON READER SERVICE CARD 21



YOUR DATA SYSTEM—HYBRID OR **HONEYWELL?**





The answer can be important to you. True, you can combine several makes of instruments into a system and get adequate results. But you usually pay a penalty for hybrid systems. There's the burden of responsibility for engineering and maintaining the system. There's the question of whether it will do what you want it to. There's the problem of modifying various makes of components to work together. And there's the inconvenience of buying instruments and spare parts from several suppliers instead of one.

Single-Source Responsibility. You avoid all of this with an all-Honeywell data processing or automatic control system. All components, from primary measuring elements to final controls, are supplied by Honeywell. If your requirements call for an analog or digital computer, Honeywell can supply it. From our systems engineers you get the advantage of experience gathered over 75 years of measurement and control work in scientific, military and industrial operations. And Honeywell takes full responsibility for the system, from initial planning through installation and startup, and even including maintenance.

Conserve your Working Capital. You can conserve working capital by leasing a Honeywell system from one to five years, paying for it as you use it. Because you lease at today's prices, you're protected against possible future price increases. Because you deal *only* with Honeywell, you needn't worry about long negotiations with third parties.

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PIONEERING THE FUTURE

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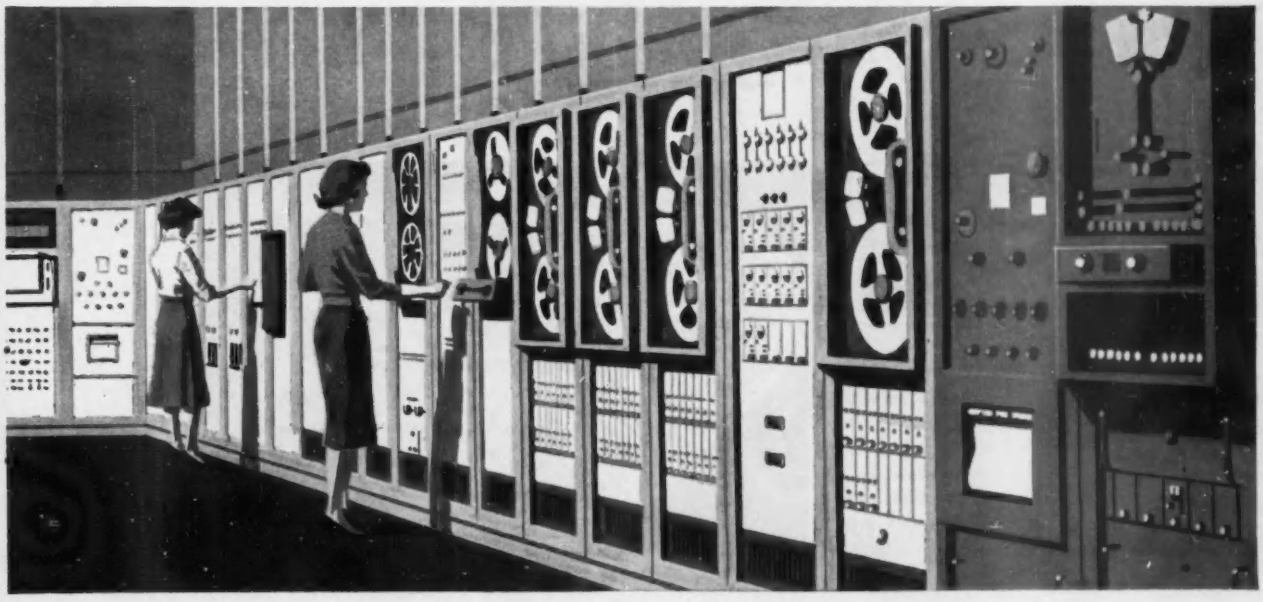

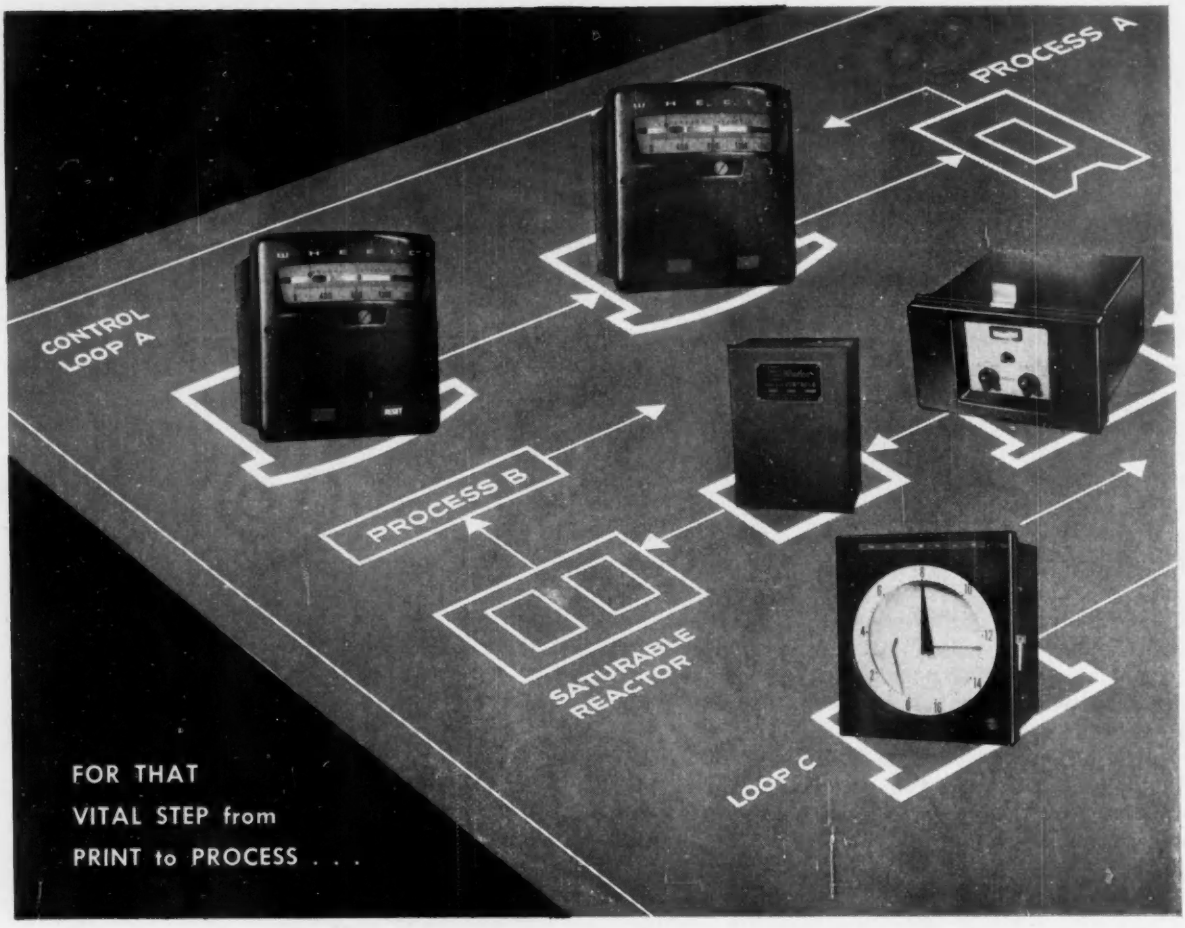

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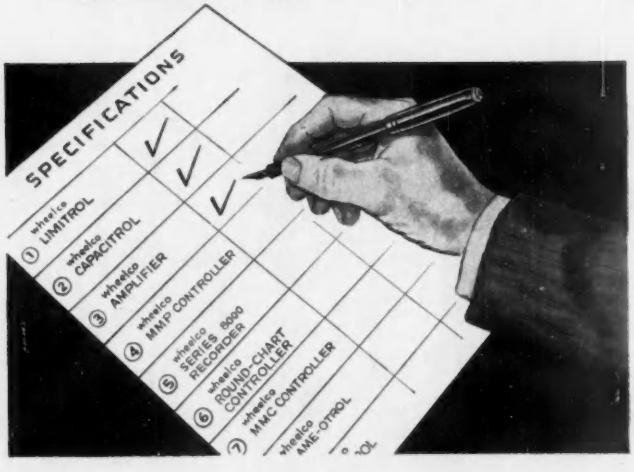

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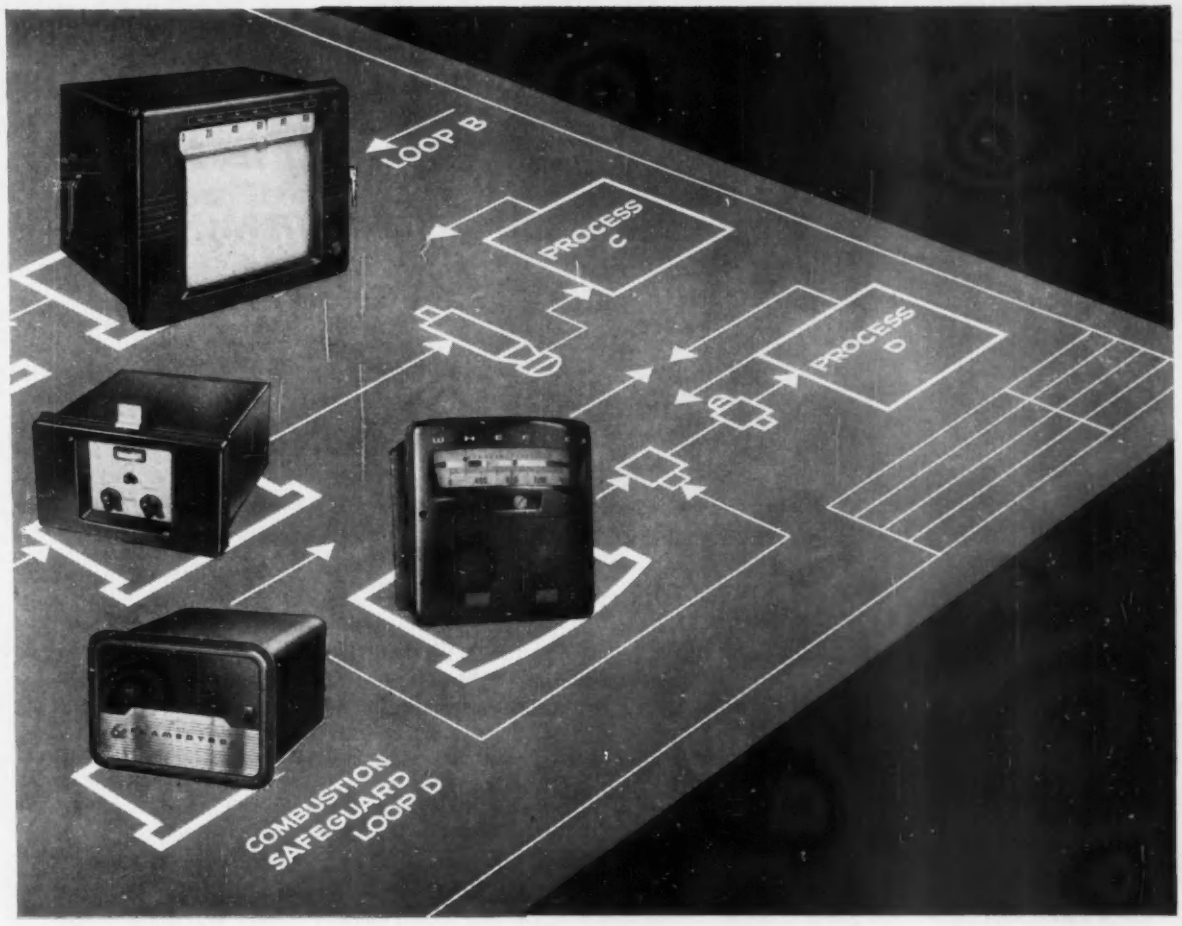

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You can rely on Wheelco to implement your ideas for the best in process control • a broad line of flexible accurate instruments • a solid reputation for instrument dependability • experienced engineering with twenty-five years of process instrumentation • nation-wide service network of Wheelco offices, staffed by skilled engineers • modern plants, production techniques, and a dynamic research and development program. Talk to the man who brings these advantages with him — the Wheelco Sales and Service Engineer. He will help make the vital step from one-dimension planning to three-dimension reality. Why not call him today?

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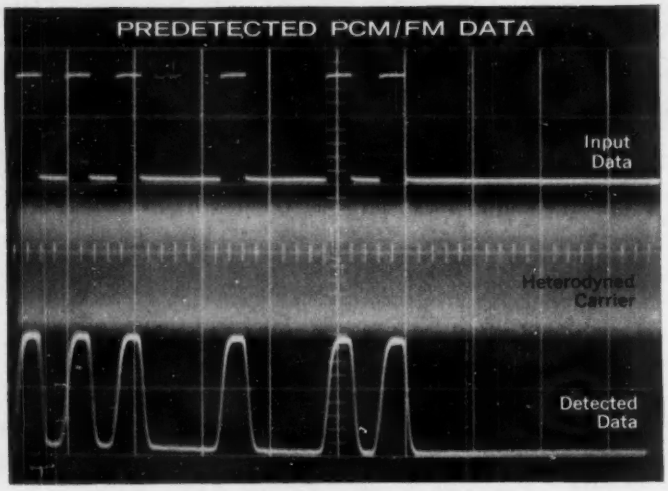

5.0-mc IF carrier heterodyned down to 750 kc. Random-spaced pulses, 20 μs on-20 μs off-type information. Sweep rate: 50 μs/cm.

ONLY THE MINCOM CM-100 IS NOW PERFORMING OPERATIONAL PREDETECTION RECORDING

...and actually doing it at defense facilities as you read this advertisement

Months of exhaustive field testing prove that the Model CM-100, Mincom's latest instrumentation recorder/reproducer, is capable of performing predetection recording on an everyday operational schedule. Because of the CM-100's 1-megacycle response and constant phase equalization at all speeds, an original IF signal of 5.0 mc can be heterodyned so that the carrier and its sidebands fall within the system's frequency range.

Standard Production Model

In this standard production model, Mincom has reduced the series elements before data storage to receiver and mixer only, one step from the antenna. CM-100 thus records and reproduces the sidebands and carrier swing of a receiver intermediate frequency—and it does this with FM, FM/FM modulation, PCM and PCM/FM.

Compatible Recording, Phase Equalization

With Mincom's predetection reception and playback, recording ground stations can be universal in the sense that all types of data systems can be handled by the same equipment. Uniform phase equalization at all speeds means that recorded predetected signals can be reduced in speed and studied with consistently good pulse response, using tunable discriminators.

Versatile System

The Mincom Model CM-100 does the work of two magnetic tape systems by storing both analog and pulse data with equal facility. It is also capable of recording and reproducing greater bandwidths at slower speeds, making possible longer recording times—from 3 hours and 12 minutes at 62.5 kc—7½ ips, to 12 minutes recording 1 mc—120 ips.

Interested? Write today for brochure.

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T. J. Williams

makes the most of process dynamics

After listening to Monsanto Chemical Co.'s T. J. Williams present a new approach to computing-control, one in which he advocated a systems analysis of the process to find several loops that might be controlled by a special purpose computer instead of trying to bring the whole process under general purpose computer control, a listener was moved to comment, "Now here's a fellow who is talking about process dynamics and their effect on control and knows what he's talking about because he's actually used process kinetics to develop a control system. And his realistic approach is the kind of thing that comes only from long experience in industry".

The listener would have been surprised to discover that Ted Williams was in the U.S. Air Force as recently as 1956. But in the four years, since he traded his uniform for civvies, most people are willing to admit that Ted has packed in a decade of contributions to industrial process control.

Service in the Air Force has been responsible for scrambling Ted's life to some extent, though it was through his service that he was able to earn his degrees: a BSChE (1949), a MSChE (1950), a PhD (1955),—all from Pennsylvania State University—and a MSEE (1956) from Ohio State University.

Out of the Army Air Corps after World War II ended, Ted enrolled under the G.I. bill as a chemical engineering student at Penn State. In his sophomore year, he was introduced to process dynamics, through a part-time job in the chemical engineering department. To earn money to support a new wife, Ted became part of a project to determine if hold up (liquid kept on trays) was beneficial or not in distillation. His job: set up differential equations for the distillation column and solve them by hand on a desk calculator.

Throughout his undergraduate studies, Williams stayed interested in evolving and solving process differential equations for the distillation column and the interest continued into graduate school. In 1949, he started looking around for some computational help, first he used an IBM 604 calculator and then the CPC (Card Programmed Calculator).

In December 1951, having just completed his course work for his PhD degree, Williams was ordered to active duty as a first lieutenant with the Air National Guard. In 1953, he applied for additional educational training, asked to join the Air Force's nuclear engineering program because it was the only one open that would lead to the doctoral degree. Although his application was turned down he was transferred to the faculty of the Air Force

Institute of Technology where his first job was to set up a chemical engineering curriculum of 13 courses—all of which Ted taught in the three years he was there.

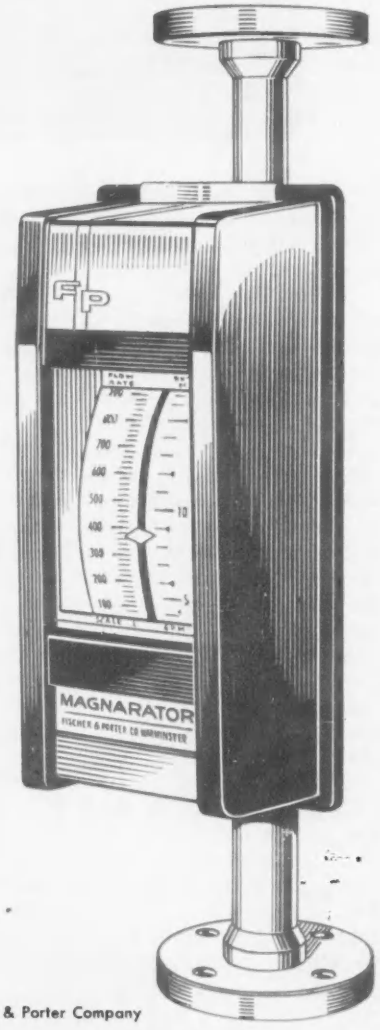
Meanwhile, Williams pursued electrical engineering courses at Ohio State (enough to win a MSEE degree) and worked on his doctoral thesis in chemical engineering. By the summer of 1956, having won his doctorate, he was ready to leave the Air Force and go into industry.

He started at Monsanto as one of four technologists hired to establish the Monsanto Systems group which was to plan ahead for the chemical company in all aspects of systems engineering: instrument testing, education, instrument development and evaluation, and development of theory. His first job in this new group: evaluating analog computers and choosing one for a Monsanto simulation facility.

In July of 1959, Ted was made supervisor of the Application Group in the systems section with the immediate problem of determining the status of computing-control and proposing the direction Monsanto should take.

Williams reached his conclusions on computing control the same way he attacks all process problems. He applied the systems approach, built a mathematical model which could be put on the analog computer so that kinetics could be studied. A prolific writer, he has had 82 technical papers published. And he feels he has just really started making the most out of process dynamics for control.

■ The Magnarator* is a metal or glass tube rotameter that clearly indicates flow rate and transmits a linear pneumatic output signal as well. But it is a true in-line, through-flow meter . . . no nooks, crooks, crannies, or corners. Magnarators have no fear of the most troublesome liquids and gases. Even problem slurries flow directly through without hesitation. The motion balance transmitter is a design that has proved itself inherently accurate and dependable time and time again. And in the Magnarator it is at its very best. This is an outstanding companion to our present extension-type Magnabond* flow transmitter.



*Tradename of Fischer & Porter Company

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Newsbreaks
In Control

● Top Russian Spaceman Calls for Better Control

Moscow—Fundamentally new guidance systems are needed for space exploration, Leonid Sedov, top Soviet space technologist, told a special meeting of the Russian Academy of Scientists, called to celebrate the anniversary of Russia's first Sputnik launching three years ago. He told the group that the control system which directed a Soviet vehicle to hit the moon last year was not accurate enough for such space exploration projects as a trip to Mars.

● Reed Relay for Europe

Stuttgart—The reed relay, capable of exceptionally long life in switching applications, is being introduced into Europe by Standard Elektrik Lorenz AG. Based on a design originally evolved by the U.S.'s Bell Telephone Laboratories, the new component will have gold plated contacts, hermetically sealed in a glass tube filled with nitrogen gas and a small amount of hydrogen. Expected life: many million operations.

● Japanese Project Tries Computer Talk

Tokyo—Four Japanese researchers at the government's Electro-Technical Laboratory have launched a project aimed ultimately at designing computers which can receive verbal inputs and which produce verbal outputs. As a starter the scientists have analyzed the oscillation patterns of vocal cords as they sound vowels and consonants, converted them to mathematical form. And the group has programmed a Japanese Mark IV-A general purpose computer (developed at ETL last year) to supply an audible output. Although results have confirmed feasibility, the scientists feel they need a computer 5,000 times faster than the Mark IV-A (addition time: 0.24 microsec) to get a sound similar to the human voice.

● Britain Eyes International Space Force

London—United Kingdom is sounding out a number of other countries on joining a combined space research group. Britain's Minister of Aviation Peter Thornycraft feels pooling efforts of Australia, Canada, and some European nations would give the group resources in space technology bigger than those of the U. S. or Russia. Britain wants to use the Blue Streak IRBM, which has been cancelled as a weapon. Present plans would replace the Blue Streak's inertial guidance system with a radio command control. Probable first efforts: space communications experiments.

● Competition Heats Up in Optical Reading

New York—Last month IBM started marketing its optical character recognition device as input equipment for the IBM 1401 computer system. It was the third newcomer to the field in a month. The others: Philco and Briggs Associates. Striving to maintain its lead, Farrington Manufacturing Co., will this month unveil a complete line of readers.

Sparse Attendance Shakes ISA Show

Expecting 30,000 visitors, exhibitors watched just over 15,000 registrants tour a show that was short on new developments. The question: is the ISA Show losing its audience?

NEW YORK—

When the 1960 Instrument Society of America show was set up in New York's Coliseum late in September, veteran observers noted that the show covered almost 20 percent less area than the 1959 exhibit in Chicago. But the big disappointment was recorded when the show closed and exhibitors noted the registration: just over 15,000, a little more than half the 30,000 that had been expected (last year's attendance: 25,000).

Although many exhibitors were quick to comment on the "high quality" of those who attended, most admitted they would have been happier to see the aisles at the show crowded just a few times during the five days of exhibition. The reasons for the fallen attendance were giving instrument makers cause for serious concern. At first many blamed business which was said to be soft in spots. But those exhibitors who had seen or heard about the record 42,000 attendees at WESCON in August were not so willing to blame any recession, real or imagined.

"What seems to be happening," said one worried marketing manager, "is that electronic shows are stealing ISA's audience. And because they are doing a better job of promotion and are collecting exciting and dramatic developments, these new shows are growing while ISA's seems to be drying up."

Certainly, a diligent control engineer was hard pressed to find very many new, exciting developments on display at the Coliseum. In fact, some of the most interesting conversation resolved around the prospects for special purpose digital computers, few of which were on display (for a discussion of this new development see "The Missing Market in Computing-Control" on page 95).

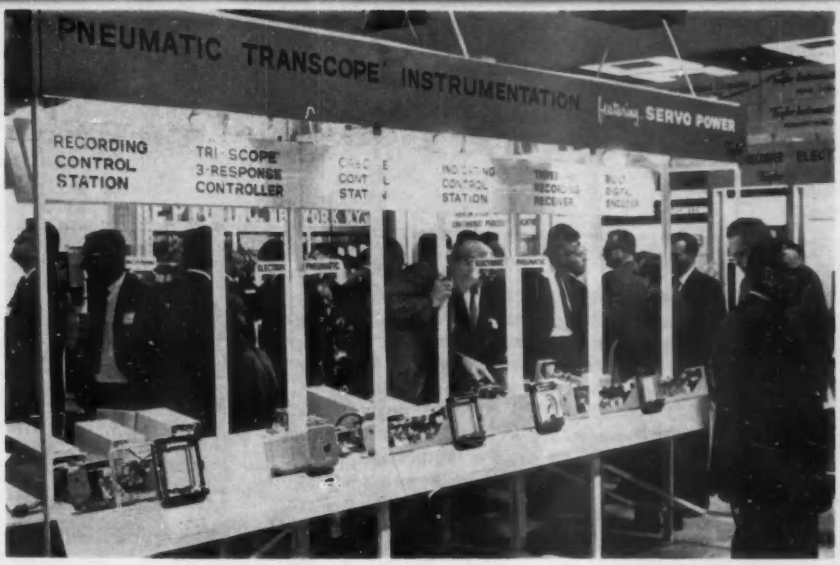
The most striking trend at the show was the return to prominence of pneumatic devices, particularly pneumatic computing elements (see photos). One reason for the renewed interest in pneumatics may have been the activity in pneumatic computing elements which visitors to the Moscow IFAC Congress in June saw at the Soviet Institute of Automechanics and Telemechanics. Another reason may have been the pneumatic computing elements (quite similar to the Russians') developed by the Diamond Ordnance Fuze Laboratory of the U.S. Army's Ordnance Dept. and displayed at the ISA show. These unique units with no moving parts (CtE, May '60, p. 26) won an ISA show award for one of its developers, B. Horton, and several manufacturers including Minneapolis-Honeywell have expressed an interest in them to the extent of building prototype units.

For the first time since the splurge of electronic process control in 1958, pneumatic control again shared equal emphasis in many booths. For example, Fischer & Porter displayed a pneumatic computing relay, a compact pneumatic indicator recorder, and a new miniature recorder. Taylor Instrument had its controllers displayed down the center of its booth—electronic on one side, pneumatic on the other. Robertshaw-Fulton exhibited a pneumatic control system for internal combustion engines and turbines just opposite the Microsen electronic control it purchased from Manning, Maxwell & Moore this year. Moore Products urged visitors to "build your own pneumatic analog computer" with components that could perform almost every arithmetic function.

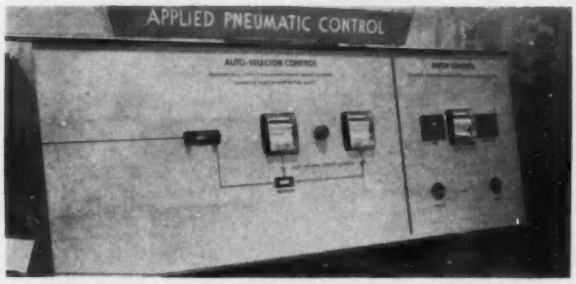
In an attempt to spread interest beyond the process control field, ISA invited a number of government research facilities to exhibit. Some of the most interesting things to be seen at the show were in the booths of such organizations as the National Aeronautics and Space Administration (a man-in-space capsule), Navy Electronics Laboratory (underwater instrumentation), Naval Medical Research Laboratory (medical instru-

Giant digital plotter, built by Gerber Scientific Instrument, has accuracy of 0.001 in. over 48 in. by 48 in. area.

PNEUMATICS MAKE A COMEBACK



At Taylor Instrument Cos.' booth, pneumatic controllers shared equal billing with electronic controllers. A display of controllers, running down the center of the booth, showed pneumatic on one side, electronic on the other.



***At Foxboro Co.'s display, applied** pneumatic control occupied an important spot.*

With pneumatic computing elements causing a stir, Moore Products emphasized an approach it has been urging for several years: build your own analog computer with commercially available modules.

***Fischer & Porter's new pneumatic miniature dial indicator** as evidence that development continues on pneumatic products.*

mentation and the National Bureau of Standards (state of the art in temperature and pressure measuring).

Among the highlights in the commercial booths were these:

► A multiple record-annunciator that records from 10 to 400 variables on chart paper mounted on a translucent, backlighted platen so that an operator can read all variables from a desk or control console. Built by Keinath Instrument Co., the device is a data logger in which information is plotted as a trace instead of being printed out as a digit. Key component is a time-shared millivolt potentiometer. The device is available with 10 to 100 frames; each frame can record 1, 2 or 4 variables.

► Giant digital plotter built by Gerber Scientific Instruments for the U.S. Army's Corps of Engineers has an accuracy of plus or minus 0.001 in. over a 48 x 48 in. area. Analog plotters of this size normally have an accuracy no better than plus or minus 0.015 in. Key component for positioning: a ball screw drive ground to 0.0003 in. accurately locates the print head which has 8 print wheels.

► Linearizing multichannel digitizer has been developed by Rosemount Engineering Company using a magnetic disc and a potentiometer. As the disc rotates, recorded magnetic bits are scanned by a reading head and counted. When the count equals the incoming magnetic signal, a null detector closes a gate, ending the count.

Tunnel Diode Oscillator for Microwaves

PRINCETON, N. J.—

Record power outputs—up to 10 milliwatts at 600 megacycles—have been obtained from a new experimental tunnel-diode microwave oscillator developed by RCA's electron tube division. Because it has been made insensitive to nuclear radiation, in addition, the new device is expected to find application in telemetry in radiation areas (such as space, nuclear test explosions, etc.), in radar systems, and in communications.

The new device can be tuned easily either mechanically or electrically. RCA has built several oscillators to operate over the frequency range from 300 to 8,000 megacycles. In addition to the power output indicated above, other oscillators have performed like this: two milliwatts output at 1,600 megacycles, 0.7 milliwatt at 2,800 megacycles, 0.2 milliwatt at 5,500 megacycles, and 0.01 milliwatt at 7,100 megacycles.

Russian-English Computer Dictionary

BERKELEY, CALIF.—

A 600,000-word dictionary has been converted to computer format at the University of California here as part of a program to automatically transiate Russian technical literature. Called RUSDIC, the mechanical dictionary will be used with an IBM 704 digital computer which looks up words for specific translation.

U. of C. instructor Dr. Sydney M. Lamb, in charge of the program, is aiming for a translation rate of 360,000 words per hour. A separate computer program has been designed to convert a conventional Russian-English dictionary to the format required in the translation program.

RUSDIC is being specially designed to translate Russian biochemical works, but the over-all system will produce intelligible English sentences out of any language for which a dictionary exists. Dr. Lamb's system, when completed, will be usable on other computers, too, translating at a rate depending on the computer. On the IBM 704 computer, digital look-up operates at a rate of about 125 words per sec.; on an IBM 7090, look-up rate is increased to 500 words per sec.

Electronic Scanner Runs Welders

TWINSBURG, OHIO—

Electronic equipment that scans 24 electrical welding units 320 times per sec is controlling welding operations at Chrysler Corp.'s stamping plant here. The gear automatically searches, controls, regulates, times, and keeps a record of the largest automatic welding assembly line in the automotive industry.

The big problem at Twinsburg was timing the welding operations because each weld requires tremendous amounts of electrical power. If two welders were to fire simultaneously, the power would drop sufficiently so that weld quality would suffer.

With the scanner, welding machines are fired in millisecond intervals and no two weld at the same instant. In building the rail and floor span assembly, 860 separate welds are required on each assembly.

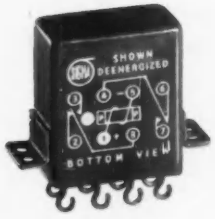
In operation, the scanner checks each welder to see if it is ready to weld. If it is, the scanner then transmits a firing signal to draw welding power.

Rapid Progress in Optical Maser Development

The optical maser, a device that offers the possibility of amplifying light the same way microwaves are amplified, is moving closer to successful application. In June, scientists at the Hughes Aircraft Co. demonstrated that a ruby crystal could be stimulated to emit coherent light. Last month, scientists at the Bell Telephone Laboratories transmitted coherent light signals 23 miles with optical masers of their own design. Purpose of the experiments was to demonstrate the feasibility of communication with light waves. The optical maser theoretically offers a method of transmitting 10,000 times as much information over a channel as can be now carried by microwaves. Big problem still to be solved: how to build a continuous optical maser. Both the Hughes and BTL devices (photo) are pulse operated units.

one man gang

- 30 G TO 5000 CPS VIBRATION IMMUNITY
- 100 MW. SENSITIVITY
- 0.80" X 0.90" X 0.40"
- DPDT (POLARIZED)
- −65°C. TO +125°C. OPERATING TEMP. RANGE
- FIRST RATE RETROFIT



The problem some people have is finding a good subminiature "on-off" relay that will work in *their* circuits—e.g., if it's really subminiature and sensitive enough, it won't take the surrounding vibration or shock . . . or it may work under 30 g's to a couple of thousand cycles, but only on watts instead of milliwatts. Worse still, the relay "works" but not according to its specs, resulting in real system troubles. The possible combinations and permutations of these individual requirements can grow to agonizing proportions.

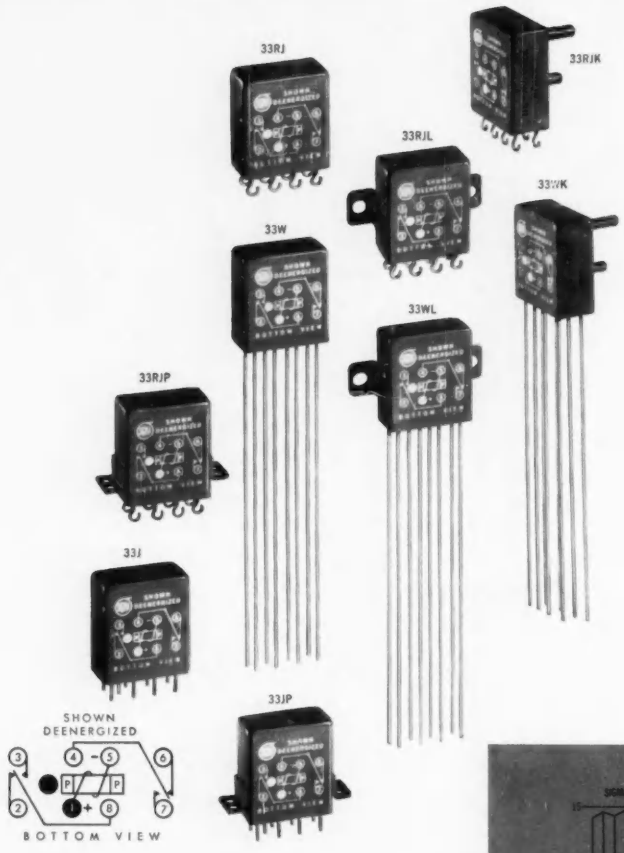
Here is a relay designed to tranquilize such agony. There is plenty of built-in safety margin to guarantee that it will work according to all the ratings published here, without any fudging. Power drain and heat dissipation are kept to a minimum by the small power requirements of the "33". And you don't have to give it more than the rated 100 mw. required, to be sure that it will always work. Calling it a "gang" may not be dignified, but if these are the specs you need in one relay, dignity is the least of your problems. The official designation is the Sigma Series 33.*

(See reverse side for major specifications)

SIGMA

SIGMA INSTRUMENTS, INC.
25 Pearl Street, So. Braintree 85, Mass.
AN AFFILIATE OF THE FISHER-PIERCE CO. (SINCE 1939)

* This isn't the magnetic latching member of the family—that's the Series 32.



PERFORMANCE

Sigma Series 33 Subminiature Relay

(See reverse side for basic design & application data.)

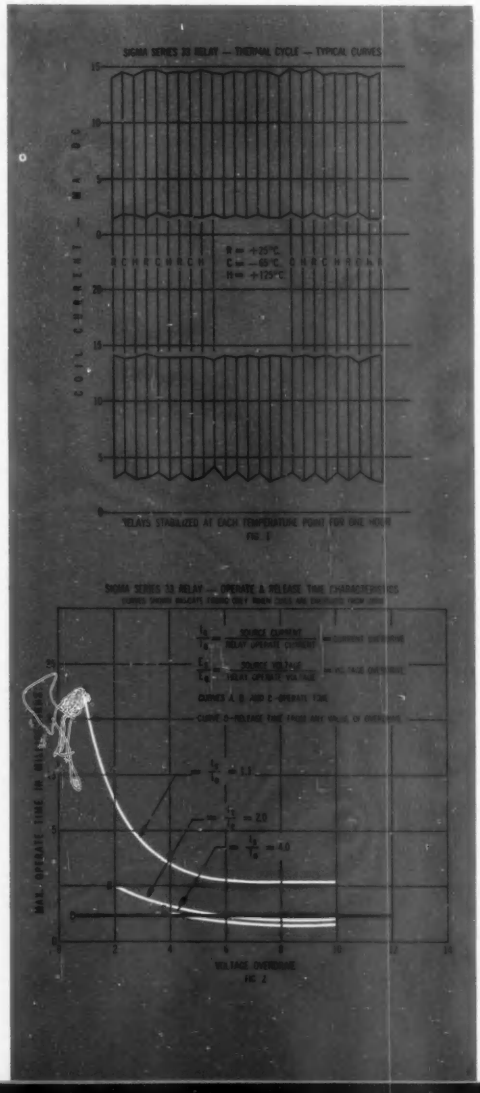
SIGNAL "INPUT"—SWITCHING "OUTPUT" The "33" is a DPDT polarized relay with magnetic bias (Sigma Form Y): when the coil is abruptly energized by a signal of given polarity and sufficient magnitude, the armature transfers from its normally-closed position to its second position; signal removal returns the armature to original position. Required energizing power is 100 mw. (VG Adjustment), or 200 mw. (VW Adjustment). Contact load rating is 2 amperes at 28 VDC/120 VAC (resistive) for 100,000 operations minimum at +125°C., max., with standard silver contact material; gold alloy contacts are recommended and available for dry circuit applications. Contact resistance is 100 milliohms, max., after 100,000 operations at rated load.

ENVIRONMENTAL CAPABILITIES The "33" will not open its contacts, whether energized or de-energized, at 30 g to 5000 cps vibration or under shock and constant acceleration of 70 g for VG Adjustment, 100 g for VW Adjustment. All ratings apply over an operating temperature range of −65°C. to +125°C.

TIMING CHARACTERISTICS AND THERMAL STABILITY of the relay are shown in the graphs, Figs. 1 and 2.

MOUNTING STYLES, CONNECTIONS, MECHANICAL DATA All series 33 relays are hermetically sealed in enclosures 0.80" x 0.40" x 0.90" high. Weight is approximately 18 grams, depending on mounting style and connections. Mounting styles available as illustrated: flange, side bracket or stud; connections: J-hook solder terminals, 9-pin plug-in or 3" wire leads. All connections spaced on 0.200" grid.

FOR FURTHER INFORMATION AND APPLICATION ASSISTANCE . . . write to Sigma, outlining in as much detail as possible your application, the relay driving and load circuits, and the required speed and rate of operation. We can then help you get the relay performance you want.



SIGMA

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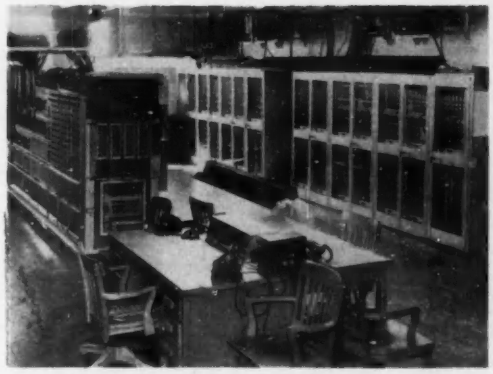
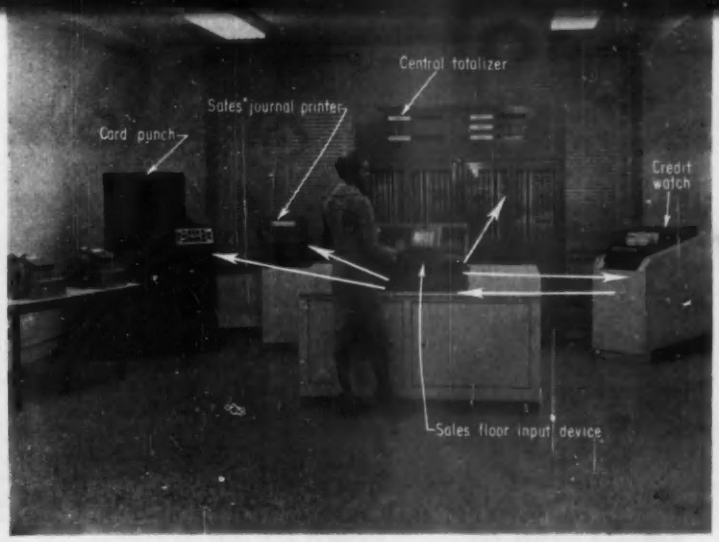
FROM RACE TRACK TO DEPARTMENT STORE



Totalisator equipment installed in the tote room of track.



Uni-Tote for department stores, showing the key components.

Totalisator for Retailer's Paperwork

A data processing system for department stores borrows techniques from the gear that runs mutuel betting at race tracks. Its objectives are to speed up customer service and provide better accounting control. But retailers are asking two big questions: Is it too expensive? Can it be kept in operation?

NEW YORK—The most sophisticated control equipment ever developed specifically for retail merchandising operations was unveiled here last month by Universal Controls. Called Uni-Tote, the data processing system connects the point of purchase automatically with credit department and a central control center where running accounting totals of a day's business are kept by the equipment. The new system performs the following jobs:

- Prints out a sales slip.
- Reviews credit customers' standing instantaneously and alerts the sales clerk if credit should not be granted.
- Prepares a punched card for every transaction—sale or return—for additional data processing such as inventory control.
- Instantly totalizes all sales, classifying them according to cash sales, credit sales, miscellaneous charges, and taxes.
- Prints each sale in a sales journal.

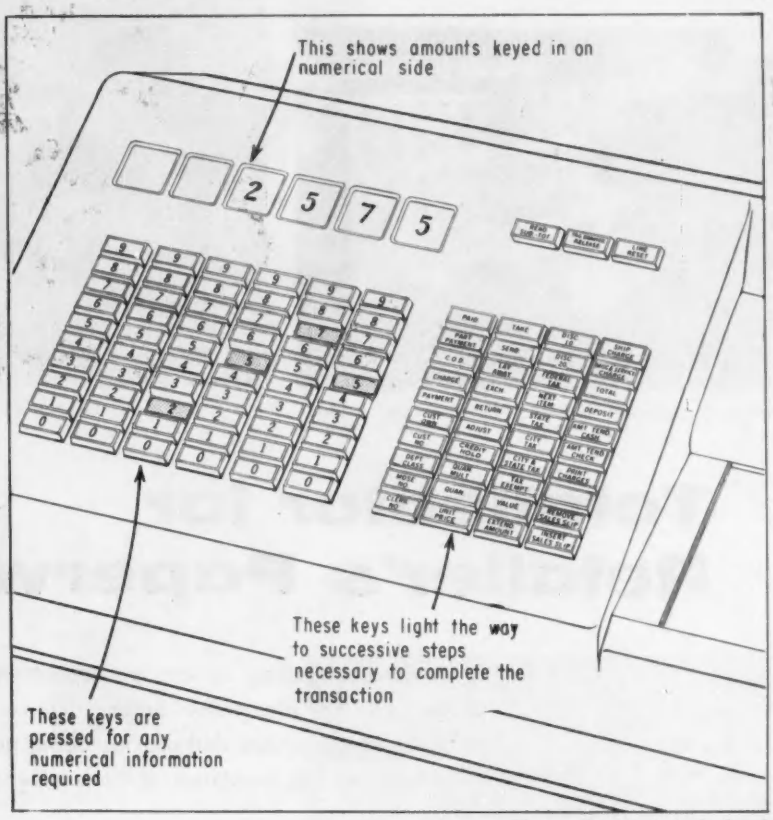
From a systems standpoint, Uni-Tote looks very much like its big brother, Totalisator race track equipment (CtE, Sept. '59, p. 36), also built by the American Totalisator Div. of Universal Controls. The most obvious similarity: all high speed computing is performed electromechanically by relays to boost reliability, instead of electronically.

Uni-Tote input equipment would take the place of the cash register on the selling floor. Resembling a cash register somewhat, the unit has many more keys which actually are divided into two groups: one for numerical information and the other to indicate transaction steps. Inside the console of the input device, relay memories store the information punched into them in 50-bit blocks. These blocks are moved to the credit department, the centralized totalisator, or the card punch on the sales clerk's command.

• **Cash register operation**—Here is how the system works. After a customer has made his selection, sales clerk puts into the input device (see next page) a punched card ticket from the merchandise, a plastic punched card identifying the sales clerk, and the customer's charge plate if it is a charge sale. As soon as the sales slip is inserted, a sequencing mechanism will light up five keys offering the clerk a choice of transactions such as: *take, send, exchange, return,* or *adjust*. After the sales clerk has pressed the proper button for the transaction underway, two other keys are lighted (and those already lit are extinguished) offering a choice of multiple quantities or just one item. If more than one item has been purchased (for example six shirts), the sales clerk then punches in the number (six in this example) on the left hand set of keys.

Punching in the multiple quantity button and the number of units causes the sequencer to light still another set of keys offering a variety of taxes to be incorporated and printed out on the sales slip. When this is complete, a series of buttons is lighted offering the choice of special charges such as shipping, gift wrapping, or service charges. After pushing a service charge button, the clerk then punches in the actual charge.

Finally the clerk punches a total button that sends the totals of the sale to the totalizer which adds it to sales figures for the day already received from other selling units. The figures carried by the central totalizer are classified according to cash sales,



Closeup of input device keyboard.

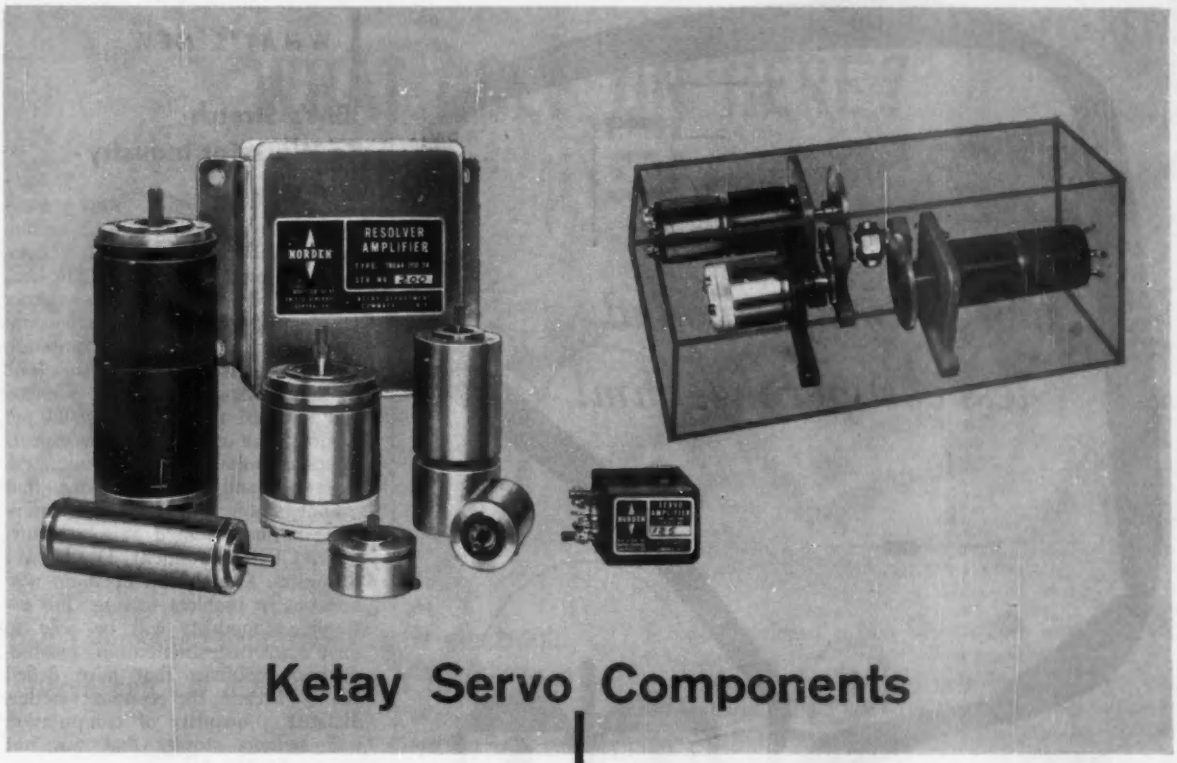
charge sales, and miscellaneous receipts from service charges.

• **Credit alert**—In a charge sale, as soon as the reader has closed on the customer's charge plate, identifying information on the customer is read and transmitted to a watch file in the credit department. A photoelectric cell scans the items placed in the file and if the customer's account is in this file for any reason, a special light warns the sales clerk that credit is to be withheld. Meanwhile in the credit department, an alarm is sounded and the customer's name and number are printed out in red. At the same time telephone communication is automatically set up between the selling point and the credit department.

If the transaction is consummated, a printer at the input device types out the information on a sales slip which becomes the customer's copy of the transaction. The same data are carried to the card punch and converted to a punched card.

• **Retailing doubts**—Discussing potential use of Uni-Tote with retailers, CtE learned that the system will force a change in many retailer's thinking if it is to be adopted. Many retailers are interested in such equipment, but had expected to find input devices that would cost from $10 to $50 each. (Although no price tag has yet been set on Uni-Tote, which is to be rented, even a monthly rental is sure to exceed the $50 limit). For one thing, a large department store such as Bloomingdale's in New York City would need at least 500 input devices. In addition, many store executives are reluctant to replace the expensive cash registers they have already purchased.

Another doubt in retailers' minds: can such complex equipment be kept running? Universal Controls points to its long reputation for reliability with racetrack betting equipment, claims it will be able to duplicate the record in retailing. But there are some significant differences. For one thing, the mutuel betting equipment involves the sending of a single pulse from a ticket seller to the totalizating equipment, whereas Uni-Tote will be transmitting blocks of digital information. And the store input equipment will have a typewriter-type printer, likely to need maintenance.



Ketay Servo Components

available separately... | or in modular packages

Ketay servo components are recognized throughout industry and military agencies for outstanding accuracy and reliability. The advanced designs and quality control techniques provide precision to satisfy the most exacting requirements of today's servo systems.

Now this same high reliability is available to your servo systems with Ketay modular packages. These packages are produced with the identical quality control procedures as are the individual components . . . and provide your servo systems with the maximum accuracy of the individual components.

* * *

Here are a representative group of Ketay components available separately or packaged in combination.

SYNCHROS. Control and torque transformers; transmitters and receivers; torque and control differential transmitters to MIL-S-20708A. Sizes 05 to 31.

SERVO MOTORS. Featuring high ratio of stall torque to power input at maximum rpm. A wide variety in frame sizes from 05 to 23. Exceed environmental requirements of MIL-E-5272A.

AMPLIFIERS. Complete range of servo amplifiers, transistorized and magnetic. Outputs from 1.5 to 9 watts, designed to operate in ambients from −55° to +125°C. Also dual channel resolver amplifiers.

POTENTIOMETERS. A wide choice of types including single-turn and multi-turn, with linear and non-linear windings, ganged potentiometers as well as sector and pendulum pots. High temperature (to 300°C) and nuclear resistant models.

RESOLVERS. Size 08 to 23 resolvers available offering functional accuracies to .03%, stability over a range of −55°C to +125°C, high input impedance. Vernier resolvers available with null spacing accuracy of 10 seconds.

FLOATED RATE GYROS. Variety of gyro spin motor and pick-off characteristics may be combined to fulfill desired specifications.

MOTOR TACHOMETERS. Integrating and damping types. Size 15 integrating model requires no warm-up time, meets environmental requirements of MIL-S-17806. Size range from 08 to 18.

For prompt, detailed information about Ketay components or assemblies, write.

NORDEN

KETAY DEPARTMENT
NORDEN DIVISION
UNITED AIRCRAFT CORPORATION
COMMACK, LONG ISLAND, NEW YORK

WHAT'S NEW

IBM's Stretch To Work for Industry

NEW YORK—

IBM's big, high speed (2 million instructions per sec) Stretch computer has been ordered by CEIR, Inc., an independent research and computer services firm; it is the first nongovernment order for such a large computer. CEIR will install the giant machine in its Los Angeles Research Center, will pay IBM a rental of $300,000 per month. The service company expects to solve problems in economics, engineering, and data processing that cannot be solved by computing equipment normally rented by a company.

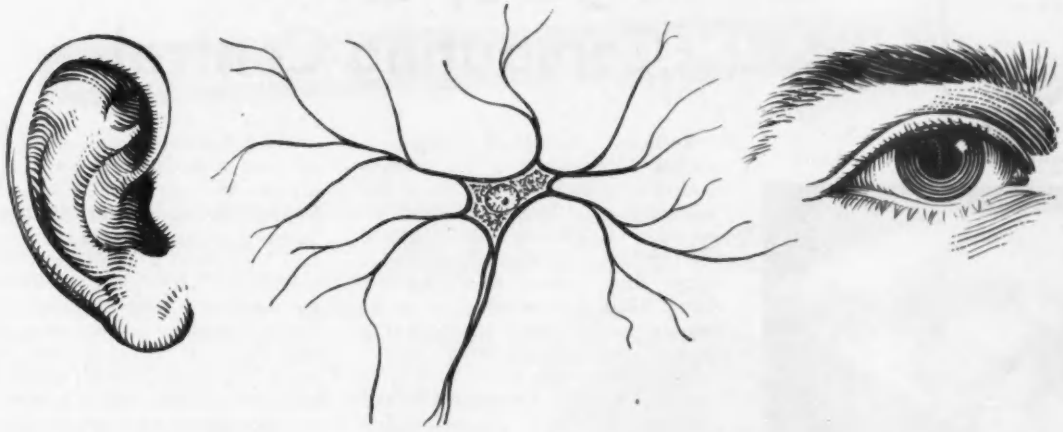
To CEIR's president, Dr. H. W. Robinson, Stretch will open up new horizons in problem solving. For example, economists will be able to solve marketing, distribution, and production problems that have defied analysis because the economic models dictated a quantity of computation and memory storage that was not previously available or was too expensive. Stretch not only can perform 75 billion computations in a 24-hour day, but its main memory can store 100,000 64-bit words, and its disc file memory holds 2 million 64-bit words. Another broad application, says Dr. Robinson, is solving complex nonrecurrent engineering problems such as three dimensional heat transfer in thermodynamics.

CEIR expects the giant computer will generate $10 million a year of business. The company estimates it will need a staff of 500 engineers, economists, analysts, programmers, and computer operators to keep the machine busy full time.

One interesting way CEIR expects to use the new machine is by subletting time to outside companies who are connected to it so that the one machine will serve a number of users. Each user might have its own input-output equipment on its property to be tied into Stretch by a data transmission system. The arrangement would give a number of companies the capability of a Stretch computer without requiring the installation of such a large, expensive machine. The design of Stretch allows it to work on several different problems at the same time.

Los Angeles was chosen for this pioneering installation because of the LA area's tremendous demand for computer time expressed by defense and commercial businesses.

WHAT GOES ON HERE?



Bell Telephone Laboratories' new electronic "nerve cell" is a step toward finding out

One fascinating area of communications has long resisted exploration—what happens inside the nervous system when you see, or when you hear.

This area is of special interest to telephone science; knowledge of how the nervous system handles sound and picture signals can help determine what information is essential to perception. This in turn may lead to more efficient communication instruments and systems.

To probe the mystery of nerve activity, Bell Telephone Laboratories scientists have developed an electronic model of a living nerve cell or neuron. Consisting of transistors, resistors, capacitors and diodes, the "artificial neuron" exhibits many of the characteristics of a living neuron; for instance, "all-or-none" response and fatigue.

In one experiment at Bell Laboratories, a network of artificial neurons is subjected to a stimulus from light through a set of photocells. The network can distinguish specific patterns of light and dark, thus duplicating roughly some of the eye's basic reactions to light. Similar studies are underway to explore our hearing processes.

At present, too little is known about neural action to permit exact electronic duplication. But experiments with artificial neurons can provide suggestive clues, contributing to a stimulating interplay between electronics and neurophysiology which may help workers in both disciplines.

The human nervous system, including the brain, is the most efficient and versatile data processing system known; and data processing is an essential part of communications. The artificial neuron provides a new approach to investigating and understanding basic nerve network functions. It is a fresh example of how Bell Telephone Laboratories constantly explores new frontiers to improve America's communications system, now and in the years ahead.

Network of neurons is assembled by L. D. Harmon of Bell Laboratories, the initiator of this new research. Many kinds of assemblies are possible.

A single artificial neuron. It delivers electrical impulses when stimulated, like a living cell. Neurons are also being used for research into hearing.

BELL TELEPHONE LABORATORIES

WORLD CENTER OF COMMUNICATIONS RESEARCH AND DEVELOPMENT

Big Day for Computing-Control

Technical details of computing-control applications in the process control industry have been almost impossible to get. Most of the pioneering users, like Texaco, Union Carbide, and Du Pont, have maintained a tight-lipped silence about what they are doing. But last month, two working computing-control applications a thousand miles apart were demonstrated on the same day.

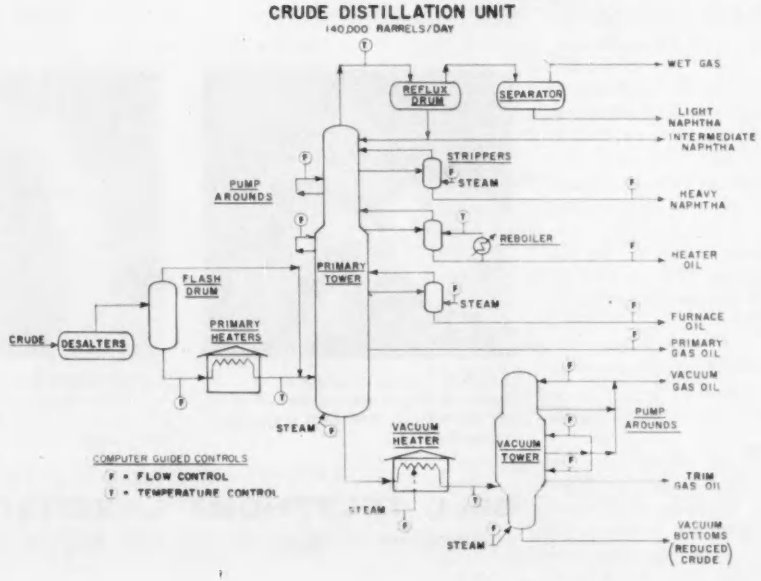
Both Monsanto Chemical Co. and Standard Oil Co. of Indiana picked October 13 for their demonstrations. Outside New Orleans (at Luling) at Monsanto's Barton Plant, a TRW Computer Co. RW-300 was seen controlling an ammonia-making process (see page 103 for a special 12-page report on this installation). Meanwhile at a Whiting, Ind., refinery, SOIND engineers were showing how an IBM 704 computer was being used in open-loop control of the world's largest crude unit.

• **SOIND'S start** – Reports about SOIND's project have been making the rounds of industry meetings for almost two years, but it was only last spring that the oil company decided to proceed on its 140,000 barrel a day crude distillation unit (for a brief account, see CtE, June '60, p. 40).

What had been responsible for the decision to move ahead was the success of a study on a smaller unit. Collecting 100 instrument readings of temperature, pressure, and flow every four hours from a 60,000 barrel a day unit, SOIND researchers put the data on punched cards, then calculated material and heat balances on an IBM 650 computer. Using statistical techniques the researchers refined the calculations and obtained suggested control adjustments that operators would never have made without the computer diagnosis.

Cheered by success on the smaller unit, SOIND decided to extend computer control to the large crude unit for three reasons: it involved a large total dollar value of product; it had frequent fluctuations of significant, uncontrollable variables such as feed quality; and it had to perform with a large number of constraints such as product quality, heat loads, etc.

• **Open loop**–SOIND programmed its IBM 704 computer, normally used by the engineering department for scientific problem solving, to scan 196 inputs of immediate operating data, to compare them to previous data in a sophisticated averaging routine, and then to calculate optimum operating



Inland d-c torque motors

provide direct drive servo positioning . . .

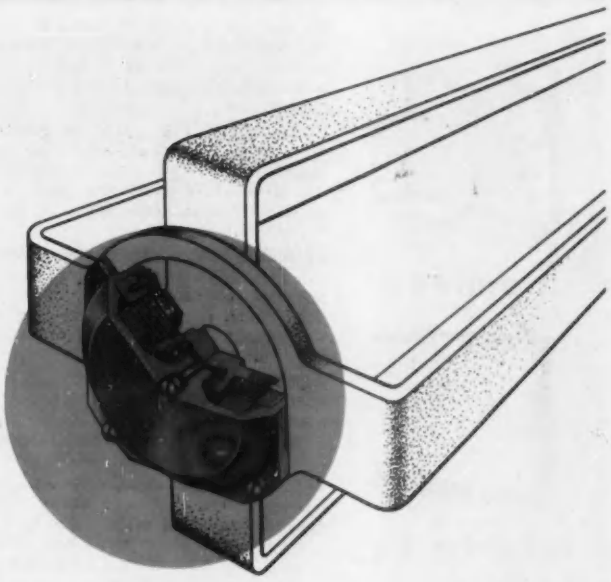
NO GEARS, NO BACKLASH

Complete range . . . 0.1 to 3,000 pound-feet

Inland offers a complete line of compact d-c torquers for airborne, shipboard or ground service stabilization and tracking systems. Increased system accuracy has been achieved by mounting the torquers directly on the driven member. This completely eliminates gear backlash and other problems normally associated with gear trains, reduces substantially over-all friction error, and improves the over-all constant of the system. In addition, Inland's d-c torquers combine the compact pancake shape with very high peak torque, low input power, and high angular resolution.

Exclusive commutator and brush rigging design

Inland has achieved this compact pancake shape while maintaining the low-power input to high-torque output ratio of a d-c torquer.



INLAND AMPLIFIERS—Inland makes a wide line of control amplifiers for systems duty with Inland torquers. Write for technical details.

COMPARE THESE RATINGS WITH A TYPICAL SERVO MOTOR-GEAR TRAIN COMBINATION

	T-2136-A	T-2136-B	T-2136-D
Peak torque, oz. in.	35	35	35
Volts at peak torque, stalled at 25°C	26.0	20.6	33.5
Amps at peak torque	1.6	2.0	1.3
Total friction, oz. in.	0.8	0.8	0.8
Rotor Inertia, oz. in. sec^2	.007	.007	.007
Weight, oz.	9	9	9
Dimensions (inches):			
O.D.	2.81	2.81	2.81
I.D.	1.00	1.00	1.00
Thickness	.63	.63	.63

For complete data on these or other Inland d-c pancake torquers, address Dept. CE, Inland Motor Corporation of Virginia, Northampton, Massachusetts.

INLAND MOTOR CORPORATION OF VIRGINIA
A SUBSIDIARY OF KOLLMORGEN CORPORATION
NORTHAMPTON, MASS.

WHAT'S NEW

conditions for the crude unit.

The 704 computer was used because it was available. SOIND has not yet decided on a computer for future projects, but because the 704 was originally installed for problem solving (and still is the workhorse of engineering, its use in process control dictated some special hardware.

In a newly built annex alongside the still's control building, a terminal unit was installed to connect process signals with the data processing equipment. After analog process measurements are brought into a solid state logic unit which sequentially scans the 196 inputs in 75 sec and amplifies and digitizes them, the data are coded for transmission by telephone line to the computer center one mile away where they are converted to punched cards or enter the machine directly.

Added to the computer is a "real time package" that can receive or transmit digital signals to and from the terminal equipment. Output of the computer is transmitted to an electric typewriter which prints out a computed setpoint for controllers. At present the still operator reads the printout and makes his controller adjustments manually, but SOIND has plans to close the loop, going directly from computer to controllers.

Purpose of the computing-control on the giant crude unit is to optimize profit. SOIND engineers developed a profit equation to obtain the best settings for 19 variables. The technique relies on linear programming with 54 dependent variable equations

Navy Eyes Automatic Ships

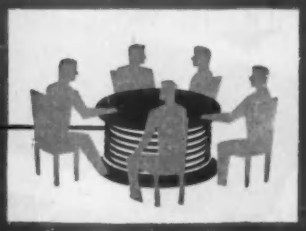
Project Dyna is a study to reduce operational costs of Navy ships with more instrumentation and automatic control.

WASHINGTON—

The Navy may turn to more instrumentation and automatic controls aboard its ships to combat rising operational costs. Operating under the code name Dyna, a small group of officers in the Office of Naval Research is exploring ways to increase mechanization of ships now.

What stimulated Dyna: Navy ships are getting increasingly complex as new feature after new feature is added. And as the ships grow in complexity, it takes an ever increasing number of men to operate them. Combined, these two factors are mushrooming the

WIRE AND CABLE ROUND TABLE



You have asked...

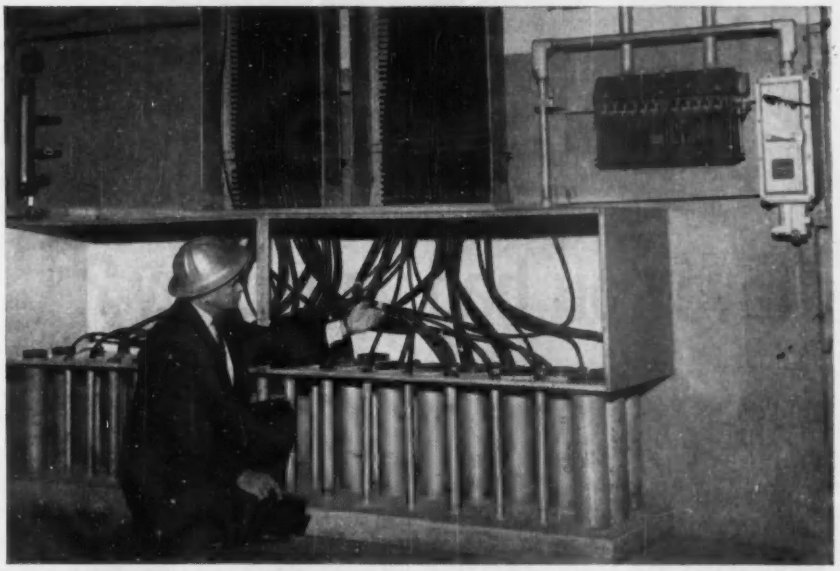
Q. How is polyethylene tested for thermal stress cracking? And is there a standard test?

A. There are a number of tests for investigating thermal stress cracking (cracking which appears as a result of high-temperature exposure combined with mechanical stress in the material when neither temperature or stress alone would cause cracking). One of the tests involves wrapping an insulated wire around its own diameter and placing it in an oven at various temperatures. Then the length of time required for cracks to appear is noted.

If the resin is susceptible to oxidation, a nitrogen or other inert atmosphere must be used. When comparisons are to be made, it is necessary to take into account the size and type of the sample, its previous history, the test equipment and conditions, including the type of atmosphere. Users of wire and cable usually need not concern themselves with thermal stress cracking because, as a rule, no resin manufacturer will offer, and no wire manufacturer will use, resins that are in the least prone to thermal stress crack or to oxidative embrittlement.

Field failures from this problem should be unknown, since the suitability of a PE is usually determined long before the material appears on wire. Nevertheless, thermal stress cracking should not be disregarded, particularly if a user or manufacturer is contemplating some sort of new or exotic resin. Resin selection always should be made on a basis of clearly defined end-use properties.

Du Pont does not manufacture wire and cable, but supplies thermoplastic resins to the wire and cable industry.



The dramatic space savings made possible through the use of control cables protected with Du Pont ALATHON polyethylene resin and ZYTEL nylon resin are shown in the illustration above. The newer cables (above) in the tray distribution system are connected to an older conduit system (below), which requires considerably more space.

Dramatic space savings possible with control cables using ALATHON® and ZYTEL®

Depending upon the number and size of the conductors, control cables using ALATHON and ZYTEL can save 20% to 35% in thickness over the elastomeric constructions in the same class. Thus many more conductors can be installed in existing conduits, or additional space can be saved through the use of economical tray distribution networks.

The superior insulating qualities of ALATHON permit a thinner insulation of .015" to .030". As a secondary insulation, a .004" to .006" skin of ZYTEL imparts exceptional abrasion resistance. Wear from flexing at contact points, and failures due to rough handling at termination points are virtually eliminated.

A high molecular weight jacket of ALATHON withstands weathering, environmental stresses, corrosive elements, and abrasion. It allows miles of cables to be pulled through serpentine tray networks without fear of "skin-back" or other physical faults, and where extreme mechanical abuse or chemical attack pose a problem, an outer armor of ZYTEL insures reliable service.

You may find that the use of ALATHON and ZYTEL will give *you* increased reliability at lower cost. Find out how by consulting your wire and cable supplier, or write for Du Pont's technical bulletin, "Signal and Control Cable Design." Address: E. I. du Pont de Nemours & Co. (Inc.), Dept. E-11, Rm 2507A, Nemours Building, Wilmington 98, Delaware.

In Canada: Du Pont of Canada Limited, P. O. Box 660, Montreal, Quebec.

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ALATHON® POLYETHYLENE RESINS | **RULAN®** FLAME-RETARDANT PLASTICS | **ZYTEL®** NYLON RESINS

WHAT'S NEW

costs of building and operating ships.

The Dyna group wants to design from scratch a group of modern vessels using the most advanced technology available. The propulsion system of ships is a good example. First the Dyna officers want to reassess the traditional use of steam propulsion in ships. One thing it wants to study is the use of gas turbines to power ships. And as nuclear power wins acceptance, it will be a leading contender for some, if not all, major Naval vessels.

Even working with the conventional steam plants, Dyna thinks automatic controls can reduce shipboard personnel to a half dozen or less in this area from the 50 to 60 men presently used to operate a ship's propulsion system.

Further mechanization in the fields of communication and navigation should produce similar results. And maintenance crews aboard ship could be pared to the bone if the Navy established reliability criteria comparable to those now applied in similar industrial operations.

Even such housekeeping jobs as record-keeping could be automated to free shipboard personnel for more productive jobs. The Dyna officers want to automate paperwork procedures for essential records.

Cutting manpower requirements for its ships means real dollars and cents savings to the Navy. For example, as the Dyna group envisions it, a destroyer that now carries a complement of about 265 officers and crew may be reduced to only 30 to 60.

This adds up to impressive dollar savings when viewed on a fleet-wide basis. For example, as an average it is figured that over the 20-year life of a ship, a reduction in complement by one officer saves $212,000. For every enlisted man eliminated, a saving of $122,500 is achieved.

Promising as the Dyna concept of a new Navy appears, the small cluster of officers working on the project know that it is still a long way off. The next step is for the group to work out more detailed plans and have them approved by top Navy Brass. If this is accomplished, then a series of specialized studies would be started in all major elements of shipboard construction and operation.

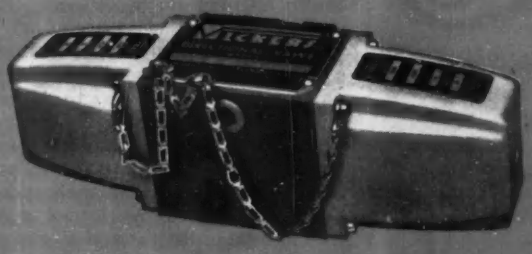
Eventually, a prototype vessel—probably a destroyer—would be built to test out new ideas. At the earliest by 1970-1975, the Navy may see such vessels as Dyna envisions operating on the high seas.

—S. Payne
McGraw-Hill News

Improved reliability • Greater capacity • No increase in price

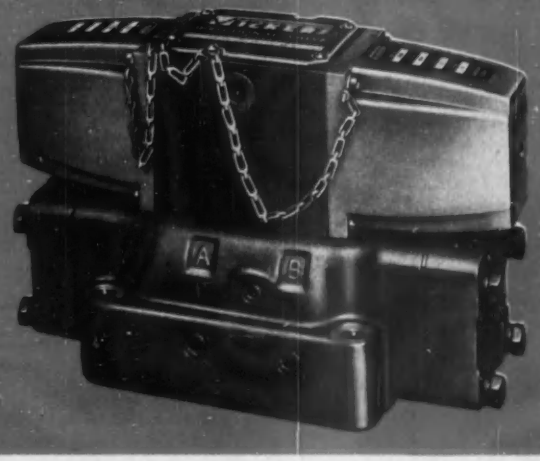
NEW DIRECTIONAL VALVE DESIGNS WITH VICKERS Q-E-L* SOLENOIDS

- New Q-E-L* solenoids assure quiet, cool operation plus shock-free performance through superior cushioning.
- Four to five times more cycle life than previously obtainable with ordinary air-cooled solenoids.
- Capacity increased from 50 to 500% on new designs.
- All models suitable for pressures to 3000 psi.
- Complete range of sizes available for maximum flows to 440 gpm.



MODEL DG4S4 is rated at 8 gpm (with nominal pressure drop) with a maximum allowable capacity of 12 gpm without malfunction. Maximum recommended operating pressure is 3000 psi. Standard subplates are available with ⅜ in. or ½ in. pipe thread ports. SAE straight thread port connections can also be provided.

MODEL DG5S4 solenoid-controlled, pilot-operated valve is rated at 30 gpm (with nominal pressure drop) with a maximum capacity of 80 gpm without malfunction, depending on circuit conditions and valve type. Standard subplates are available with ¾-in. and 1 in. pipe thread connections. SAE straight thread port connections can also be provided. Write for Catalog 5001-C.



8596

* Q-E-L designates Quiet Extended Life solenoid—a *Vickers exclusive.*

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DIVISION OF SPERRY RAND CORPORATION
Machinery Hydraulics Division
ADMINISTRATIVE and ENGINEERING CENTER
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WHAT'S NEW

Mathematicians Ride High At First JACC Conclave

CAMBRIDGE, MASS.—

To assuage the complaint of "too many technical meetings" in the control field, five U. S. technical societies —ASME, IRE, AIEE, AIChE, and ISA—are sponsoring one annual technical conference to span the full gamut of control. Hosted by the ASME, the first annual Joint Automatic Control Conference drew 750 control engineers to the Massachusetts Institute of Technology campus in September to hear three days of presentations that ranged from high level mathematics to practical hardware applications. One apparent trend that could be noted from this unified gathering: mathematics is destined to play a bigger role in control.

In fact, in what might be called the "high level sessions", mathematics practically took over. From papers, discussions, and questions at these sessions, one thing became clear: classical mathematical techniques are being resurrected in greater numbers by mathematically-minded control engineers—or perhaps more correctly, control-oriented mathematicians – for understanding complex systems.

Some typical subjects: optiomal switching, dynamic programming, optimum multivariable control, and linear filtering and prediction theory.

One concern of some listeners was that the mathematics might so eclipse the control aspects that applications would be replaced by abstract exercises in logic in the theoretical presentations. Some theoreticians apparently shared this concern, were careful to point out such limitations as this: finding general mathematical forms for systems problems is not enough. In one of his several erudite presentations, R. Kalman of the Research Institute of Advanced Study emphasized this point by noting that equations, to be useful, must be put into a form in which numbers can be inserted—specifically, they must be formulated so they can be solved on a digital computer.

Other theoreticians strove to introduce hardware into their presentations to keep them from assuming a too academic tone. In several papers on adaptive control, for example, hardware approaches were described even when the investigators had tackled somewhat trivial problems. In one, a speaker talked about changing model dynamics while describing a system that merely adapted the steady-state

gain. And he used the term adaptive to describe what might have better been called feedforward.

• **Lyapunov's second method**—Typical of the new trend to employ complex mathematics is a technique known as "Lyapunov's second method", which was originally developed almost 50 years ago in Russia. Sudden awakened interest in the technique in the Soviet Union has jumped across the world to kindle avid curiosity in the United States. The day before the JACC formally opened, early birds attended an AIEE Feedback Control System Committee Workshop on the technique.

In an introductory paper Yale University Prof. W. J. Cunningham explained to 90 invitees the fundamentals of Lyapunov's approach: a stable system can be characterized by stored energy which is itself a positive quantity with a negative time derivative.

"This concept of energy and its rate of change", said Cunningham, "is extended in Lyapunov's second method. . . . A more general 'Lyapunov function' is used, rather than energy itself. If a system is asymptotically stable, a Lyapunov function can be determined for the system.

"Conversely", he added, "the existence of such a function for a given system implies that the system is asymptotically stable."

In the eyes of some theoreticians, the "second method" is potentially a powerful tool for control engineers to help determine the stability of a control system. But finding the Lyapunov function for all but the simplest systems remains a difficult task. Lyapunov never developed anything on how to construct these functions and although a Russian theoretist, A. M. Letov (CtE, Nov. '58, p. 13), has described methods for constructing some functions, considerable work is still required to make the method useful in a variety of applications.

• **Applications slim**—JACC sessions on components and applications lacked the meat of the sessions on theory. Many of the papers described well known case histories without adding much new. But a few of the presentations were outstanding. For example, Princeton University's Leon Lapidus presented a significant paper on dynamics of chemical reactors, reviewing the current status and future trends and classifying reactors as lumped-parameter or distributed-parameter systems.

After three days of control discussions in Boston, most engineers were ready to agree on one point: the joint conference was a solid idea. Next year's (host: ISA) will be held in Boulder, Colo. —Harry R. Karp

WHAT'S NEW

Explosion Suppression by Explosion

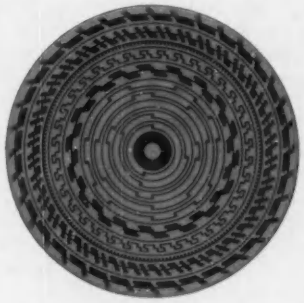
NEW YORK—

After four years of trial installation, Fenwal, Inc. is ready to market a unique explosion suppressant system that prevents serious damage from blasts by detecting an incipient explosion and extinguishing it before damage is done. Originally developed in England by the Graviner Manufacturing Co. Ltd., the system depends on the fact that most explosions are not instantaneous but start as a fire, grow as spheres, and cause a rapid rise of pressure. It is effective in preventing internal explosions.

To protect against an explosion, Fenwal installs a detector and a suppressor. When the detector, either a pressure diaphragm to sense the rapid rise of pressure or a filtered photo cell to spot the incipient flame, spots the start of an explosion, it triggers an electrical signal that detonates a cartridge, exploding the suppressor. The latter device may be a simple sphere filled with a fire killing liquid such as a halogenated hydrocarbon; it may be a quick release bottle filled with carbon dioxide; or it may be just a glass venting valve that allows explosion pressure to escape harmlessly.

Fenwal's system is useful in preventing internal explosions in which flame speed remains below 1,000 ft. per sec. It will suppress either dust explosions or blasts caused by liquid and gas combustibles. The complete operation, from detection to suppression, takes less than 25 millisec. Typical cost of an installation: between $5,000 and $10,000, depending on the volume to be protected.

The explosion suppression equipment can be tied into a graphic panel control system or monitoring system. In one application, at Monsanto Chemical Co.'s Springfield (Mass.) Plastics Div., the system was installed on a pulverizer-crusher and dust extraction system, and its operation noted only when the system shut the unit down after an incipient explosion. The equipment had been installed after an earlier blast caused by the entrance of a foreign metallic body had destroyed one crusher and blown a wall out. With the suppressing equipment in place, a similar incident occurred with only one obvious result: the equipment shut down. After inspection of the crusher, it was found that some of the plastic material had been charred, the only indication that an explosion had started.



Self-contained logic:
Norden degree-counting binary decimal encoders

Encoders in this group offer unique self-selecting V-brush system, developed by Norden engineers, to prevent ambiguity without external brush-selection circuitry. Consequent reduction in associated equipment encourages miniaturization in system design. The unit weighing only 13.2 oz.—the Model ADC-5-36BCD—translates shaft position into degrees to a resolution of 0.01°. Converters are available with both standard 8-4-2-1 and 4-2-2-1 codes.

FIVE OF NORDEN'S STANDARD DEGREE-COUNTING BINARY DECIMAL SHAFT ENCODERS:

MODEL	ADC-ST3-36BCD	ADC-3-36BCD	ADC-4-36BCD	ADC-5-36BCD	ADC-6-36BCD
Total count	360	360	3,600	36,000	360,000
Revolutions for full count	1	3.6	36	360	3,600
Accuracy 1 part in:	360	360	3,600	36,000	360,000
Mounting	Size 33	Size 23	Size 23	Size 23	Size 23

APPLICATIONS: gun turrets, antenna pattern recorders, airborne data acquisition, navigation systems, shipboard computers . . . elevation and servo azimuths, machine tool positioning tables.

SIMPLIFIED DESIGN PLUS QUALITY PRODUCTION ACHIEVE UNEXCELLED RELIABILITY

- Reduced number of components minimizes possibility of error.
- Meets Military Specifications MIL-E-5272A and MIL-E-5422D.
- Self-checking gating devices provide virtually 100% error monitoring.
- Two brushes parallel for each contact reduce noise.
- Precious metal brushes are mated to micro-finish pattern disc during run-in.
- Precision design and manufacture achieve longer life: 4×10^6 revolutions at 150 RPM under continuous full load.

RELIABILITY IS DESIGNED IN . . . AND BUILT IN BY UNUSUAL MANUFACTURING CONDITIONS

Scientists and military electronics experts testify to Norden's unusual quality control techniques. Encoder parts are manufactured, assembled, inspected and reinspected with extreme care in positive-pressure, dust-free, temperature-controlled laboratories. Norden's exceptional design and production facilities are the foundation of encoder reliability. Detailed manufacturing control specifications are available for your inspection.

Review your requirements and send for complete specifications on these or any other Norden encoders. Write, or call Milford, Connecticut, TRinity 4-6721.

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CIRCLE 49 ON READER SERVICE CARD 49

WHAT'S NEW

Computers Vie Predicting Election Winners

NEW YORK—

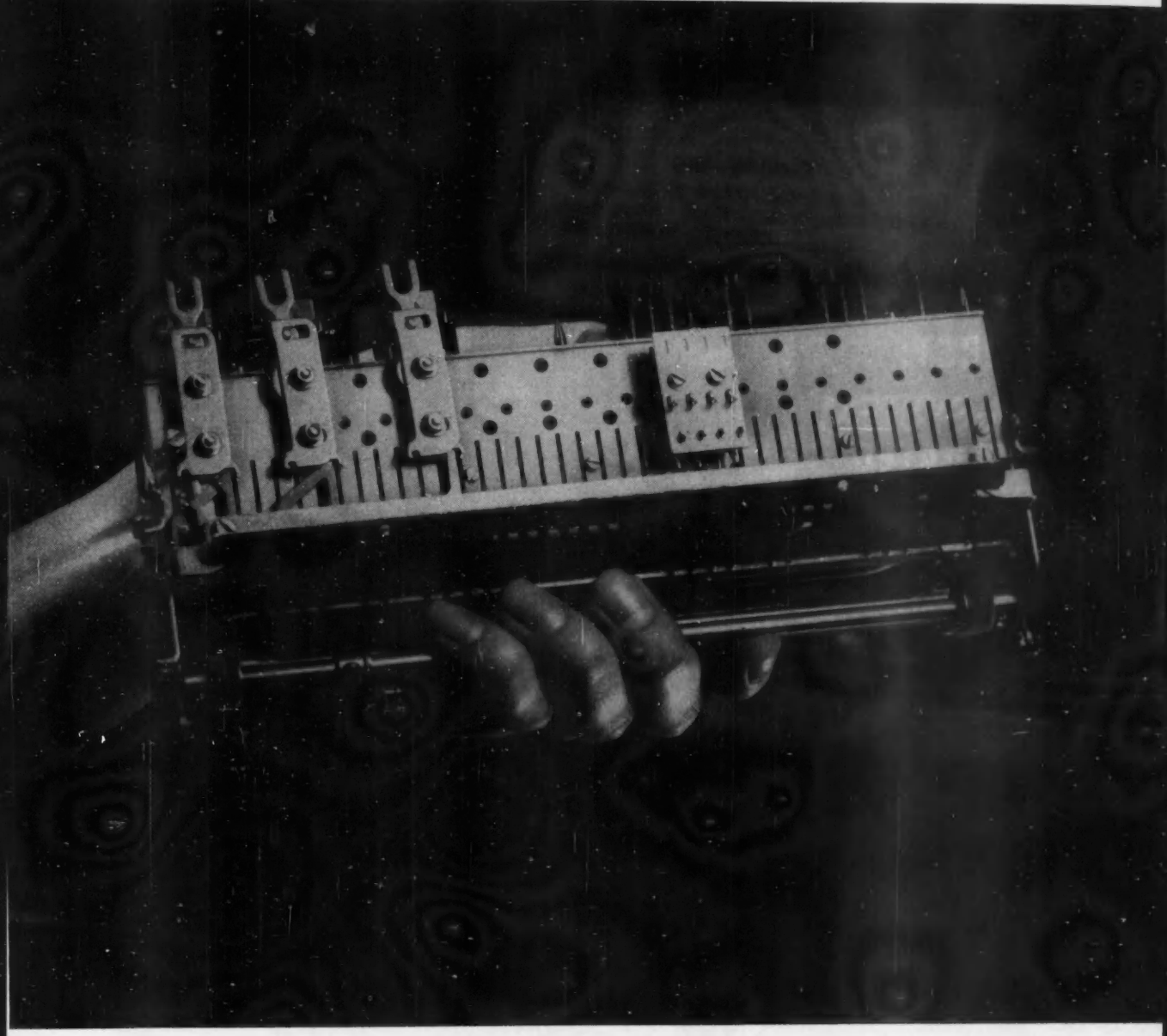
Which network has the most powerful computer? That might well be the contest radio and television networks will apparently be trying to settle on the evening of November 8, when they race to be the first to predict the winner of the 1960 national presidential election, using a battery of high powered general purpose digital computers. CBS will be running with two machines, an IBM RAMAC-305 and the IBM 7090; ABC is banking on the experience of Remington-Rand's Univac which had the election prediction field all to itself when it first started prognosticating in 1952; and NBC is introducing RCA's 501 machine to election predicting.

• **CBS's big push**—Stored in the memory of the 7090 is a mass of data on 500 election precincts and 75 marginal congressional districts, selected because most of them report early election night and are a representative sample of the total voting population. Among the data are such items as these: historical voting records for every national election back to 1928, characteristics of the voters including racial, religous, income, and residential facts.

Returns as tabulated by the IBM RAMAC will be inserted into the IBM 7090 which will first calculate odds, mathematical probabilities, on the candidates. Then the machine will answer questions to help interpret the returns. For example, the computer will tell CBS analyst Howard K. Smith such things as how Senator Kennedy stands compared to Al Smith's record in the 1928 election; whether Mr. Nixon is running ahead or behind President Eisenhower's record in 1956; is the "Solid South" continuing to vote as a bloc? Is a labor vote developing?

IBM will also be trying out some data transmission equipment on the election problem. The computers will be located at the company's New York Service Bureau and will transmit data to a high speed printer in the CBS election headquarters 2 miles away.

To prepare the system analysis and program, IBM systems people worked 16 man-months, and IBM mathematician-programmers toiled another 60 man-months. On election night, 75 IBM people will be working in the CBS studio and about 50 at the 7090 installation. CBS will man its part of the setup with 150 people.



Stunt Box—your Big Plus with Teletype printers

Built into Teletype Model 28 page printers is a control device called the Stunt Box. The function of this unique component is to provide extra control facilities for both local and remote operations. Thus—in addition to transmitting, receiving and recording messages and data—the page printer can be used for a variety of switching, remote control and selective calling tasks.

The Stunt Box reduces costs by simplifying equipment needs and systems arrangements. It is the Big Plus—the extra value in Teletype Model 28 page printers and automatic send-receive sets.

Teletype Corporation manufactures this equipment for the Bell System and others who require the finest in data communications equipment.

Write for free 20-page brochure, "The Teletype 28 Stunt Box," to Teletype Corporation, Dept. 26F. 5555 Touhy Avenue, Skokie, Illinois.

Typing Tape Punch

Tape Reader

Send-Receive Page Printer

Automatic Send-Receive Set

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CIRCLE 51 ON READER SERVICE CARD

Nimble fingered Autonetics production workers assemble VERDAN computers for the inertial guidance system of the Hound Dog and for Polaris submarines.

Control Business Cures Aircraft Slump for NAA

North American Aviation's Autonetics Div. has leaped ahead of the company's aircraft divisions' sales and is now the second largest electronics firm in southern California.

LOS ANGELES—When V-J Day in 1945 found sales of North American Aviation, Inc. sunken to peacetime lows—the last of the famed B-25 Liberators had long since come off the assembly lines—NAA determined not to fall back on the hand-to-mouth existence of pre-World War II days. The company developed a carefully planned diversification program. Just one phase of the program, a small research group set up to investigate the control problems associated with supersonic flight, has paid off handsomely.

Early this year, NAA's Autonetics Div. in Downey, Calif., an outgrowth of that early research group, became the company's largest operating unit, noticeably surpassing North American's aircraft divisions, producers of the B-25 and later the F-86 Saberjet and F-100 Supersaber.

• **Swing to electronics**—Actually Autonetics' recent growth has been little short of amazing: in the spring of 1958, Autonetics employed about 6,000. Currently its work force is at 22,000—for close to a 270 percent increase. This surge has established Autonetics as southern California's largest electronics firm, topped only by Hughes Aircraft Co. with an employment of 28,500. Since NAA does not divulge divisional sales figures, no official sales comparisons are possible; but reliable industry sources estimate that Autonetics' share of North American's 1959 total amounted to well over $200 million.

To maintain control over its explosive growth, Autonetics reorganized its activities last year to follow along product lines. Product divisions now include Computers and Data Systems, Armament and Flight Control, Industrial Products, and Inertial Navigation. The last activity is Autonetics' forte—a field in which it has pioneered a number of important breakthroughs, including the inertial guidance system used by the nuclear submarines Nautilus and Skate on their historic transpolar voyages.

• **Minuteman momentum**—Largely responsible for the division's rapid growth in the past few years has been its landing of the hotly contested, multimillion dollar Minuteman ICBM guidance, control, and checkout systems contract. So far the Air Force has awarded Autonetics a $115 million research and development contract for Minuteman, but this total will be increased substantially when the expected production contract

Another example of how

You Fill Out The Tag...

You can choose your own performance features when you order a Fenwal 536 Temperature Controller. And get them in a *compact, low-cost, transistorized stock instrument!*

Basic member of Fenwal's new "500" family, the "536" *always* provides precise control action. You merely select from the following features to meet your specific needs: 1. Proportioning or On-Off Control. 2. Five standard temperature ranges from −50 to +600°F (Special ranges, expanded scales, and centigrade scales available). 3. Dial for set-point adjustment externally or internally mounted. 4. Separate potentiometer with graduated dial and knob for remote adjustment. 5. Cartridge, hex head, flange or coupling head probe for thermistor sensor. All configurations have a rating of 10A-115VAC or 5A-230VAC. *You buy exactly what you need!*

Of course, for the user who needs most of these features, it may make more sense to order a Fenwal 561 Indicating Controller . . . with indication as a *plus*. And for multi-point indication, as many as ten 536's can be plugged in to a 580 indicator. Get catalog on the complete "500" Line. Write FENWAL INCORPORATED, 2911 Pleasant Street, Ashland, Massachusetts.

Fenwal CONTROLS TEMPERATURE . . . PRECISELY

WHAT'S NEW

. . . reliability goal for Minuteman: improved 100 times . . .

comes through in a few months.

The Minutemen effort of Autonetics is an unparalled one in the controls field. As an associate contractor, Autonetics has set up a systems management division which has separate administrative, engineering, and manufacturing groups.

"The most unusual aspect of Autonetics' Minuteman program", says Autonetics president, John Moore, "is the scope of its reliability effort. Autonetics and its major suppliers are attempting to improve present levels of avionics reliability by a factor of 100." As a matter of fact, Autonetics estimates that approximately 25 percent of the cost of Minuteman development will be for reliability.

In addition to its Minuteman work, the inertial navigation group is turning out systems for the Navy's Polaris submarines and for the Air Force's Hound Dog air to ground missile. It is also producing bombing-navigation systems for the Navy A3J bomber.

Also favored with good military acceptance is NASARR (North American Search and Range Radar). It is an all-purpose monopulse radar system used to guide military aircraft to targets obscured by bad weather or darkness. NASARR has already been ordered for the Air Force's F-105D fighter-bombers and for the F-104 Starfighters being made for West Germany, Canada, and Japan.

Autonetics' military computer products also include a field artillery fire control computer for the Army. Intended primarily for fire control of tube artillery and free rocket type of weapons, the device may also be used for missile checkout, data reduction, and electronic countermeasures. Rounding out the division's military product mix are automatic checkout systems and airborne tape recorders.

• **Industrial stumbling block**—In common with most other military-oriented companies, Autonetics experienced its share of reverses in entering the industrial field. But following the establishment of its Industrial Products Div. in March 1959, marketing efforts seemed to gain greater direction and purpose. Currently this product group is pushing three major lines: RECOMP II, a small, general purpose, transistorized digital computer; NIFTE, a new, inexpensive, semiautomatic continuity checker for

(*Continued on page 198*)

Tung-Sol tubes help *CHICAGO AERIAL* keep 'copter blades on "right track"

Chicago Aerial Industries' automatic Electronic Blade Tracker brings new standards of accuracy to the critical job of tracking helicopter blades to assure that they are all rotating in the same plane, or track. Proper rotation means smoother flight characteristics, minimized vibration, reduced structural stresses and lower maintenance costs. It virtually makes obsolete the manual flag-tracking method.

The Tracker uses range finding principles to triangulate for each successive blade height. Electrical signals generated by photo-cells in the electro-optical pick-up positioned beneath the rotating blades are fed to a computer analyzer. These signals are then converted to dc voltages proportional to blade height, which registers on the front-panel meter.

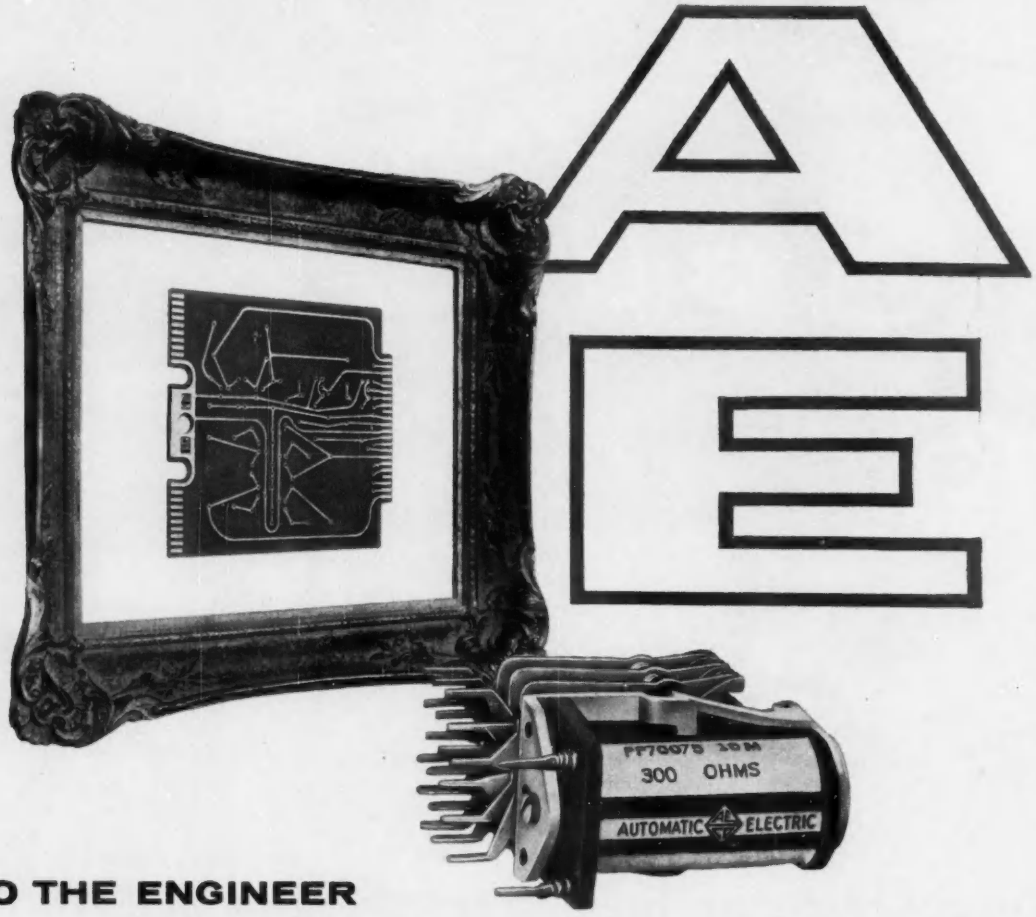
Because rigid standards of reliability are mandatory for this equipment, Chicago Aerial selected Tung-Sol tubes to handle the vital regulation function in the conversion network. Tung-Sol 5687 series regulator tubes minimize any variations in output voltage due to load current or line voltage changes. Both tubes maintain 150 volts ± 1 volt insuring the most precise readings.

CAI adds still another name to the growing list of manufacturers who are calling upon Tung-Sol tubes and semiconductors to deliver top performance reliability. Like CAI, you can get the benefit of Tung-Sol component know-how, too. Tung-Sol makes a component for virtually every industrial and military requirement. Our applications engineers will be glad to make an impartial recommendation for the component complement that will best satisfy your design needs. Tung-Sol Electric Inc., Newark 4, N. J. TWX:NK 193.

Technical assistance is available through the following sales offices: Atlanta, Ga.; Columbus, Ohio; Culver City, Calif.; Dallas, Texas; Denver, Colo.; Detroit, Mich.; Irvington, N. J.; Melrose Park, Ill.; Newark, N. J.; Philadelphia, Pa.; Seattle, Wash. Canada: Toronto, Ontario.

TUNG-SOL®

CIRCLE 55 ON READER SERVICE CARD



TO THE ENGINEER

who wants to make the most of his etchings

If your printed circuit board designs involve switching, you can count on getting the best results by using AE Class E relays with direct-connect terminals.

Series EQPC relays, with end-mounted printed circuit lugs, occupy a minimum of board space, and furnish dramatic savings in assembly and wiring time.

The AE Series EQPC printed circuit relay is a miniaturized version of the premium-quality Class B telephone-type relay, with many of its best features. Contact reliability exceeding 200 million operations can be expected.

Automatic Electric also supplies Class E relays with Taper-Tab terminals, and prewired for plug-in, with 8- to 20-prong octal plugs, with or without hermetically sealed containers or dust-tight housings.

Want details? Just write the Director, Control Equipment Sales, Automatic Electric, Northlake, Illinois. Also ask for Circular 1702-E on *Relays for Industry*, and the new *Conversion Factors* booklet.

AUTOMATIC ELECTRIC

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GENERAL TELEPHONE & ELECTRONICS

GENERAL SYSTEM

CIRCLE 57 ON READER SERVICE CARD→

π

3.14159265358979323846264338327950288419716939937510582097

symbol of precision

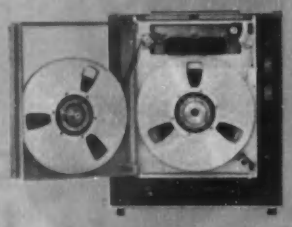
It's a simple matter for today's computer to extend the accuracy of the symbol π to a fantastic 10,000 decimal places and beyond, thanks to such advances as solid-state electronics. Thus the symbol π is a logical name for Precision's new all-solid-state instrumentation tape recorder, which has dramatically extended performance levels to literally *twice* those of ordinary magnetic tape instruments. The Precision π recorder offers:

TWICE the frequency response previously obtainable with conventional recorders

TWICE the recording time for a given length of tape—as much data on a 10½ inch reel as previously on a 14 inch reel

TWICE the economy, HIGHER reliability, LOWER flutter, LESS maintenance

Write for your copy of Bulletin 59, which describes the new Precision π Recorder, based on the thoroughly tested and field-proven design of the FIRST all-solid-state instrumentation tape recorder, the Precision PS-200 Series.



Open door view of 7-channel machine, showing loaded tape magazine which can be interchanged in 5 seconds.

Rear view of 14-channel recorder which weighs only 105 pounds, fits in only 26½ inches of rack space.

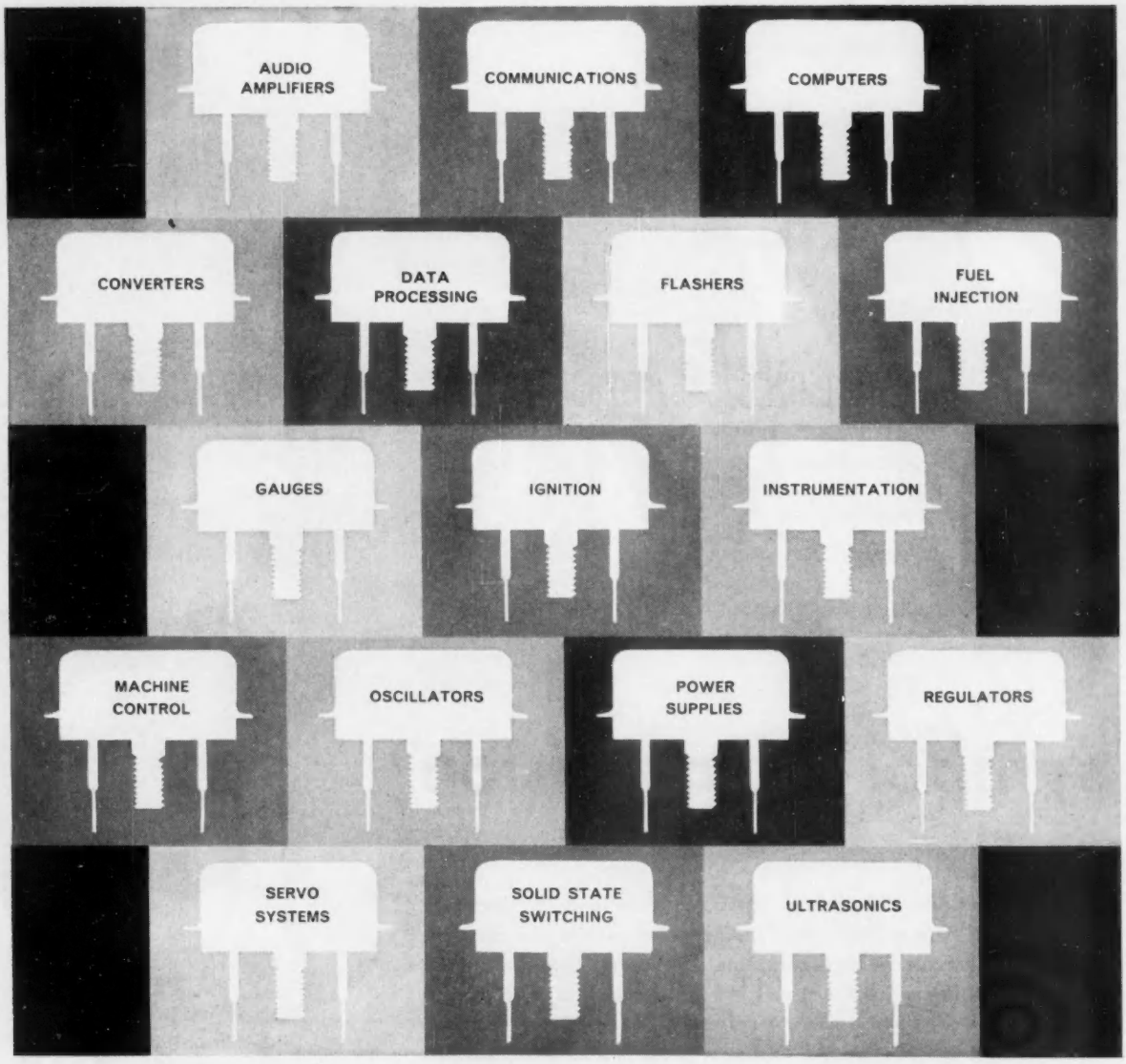
PRECISION INSTRUMENT COMPANY

1011 Commercial Street — San Carlos, California

Phone LYtell 1-4441 — TWX Scar Bel 30

Cable: PRINCO, San Carlos, Calif.

REPRESENTATIVES IN PRINCIPAL CITIES THROUGHOUT THE WORLD



DELCO RADIO—THE LEADER IN POWER TRANSISTORS

For top performance in a wide, wide range of applications, specify Delco Radio's 2N174. ■ This multi-purpose PNP germanium transistor is designed for general use with 28-volt power supplies, and for use with 12-volt power supplies where high reliability is desired despite the presence of voltage transients. ■ It has a high maximum emitter current of 15 amperes, a maximum collector diode rating of 80 volts and a thermal resistance below .8°C per watt. The maximum power dissipation at 71°C mounting base temperature is 30 watts. Low saturation resistance gives high efficiency in switching operations. ■ The 2N174 is versatile, rugged, reliable, stable and low priced. For more details or applications assistance on the 2N174 or other highly reliable Delco transistors, contact your nearest Delco Radio sales office.

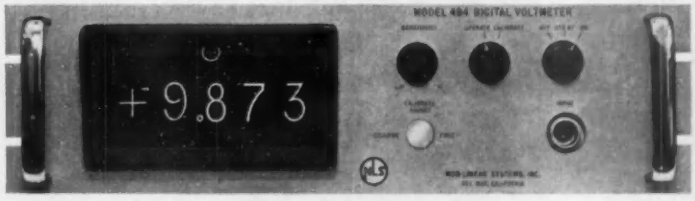
DELCO RADIO
DEPENDABILITY
RELIABILITY

Division of General Motors · Kokomo, Indiana

Newark, New Jersey	Santa Monica, California	Chicago, Illinois	Detroit, Michigan
1180 Raymond Blvd.	726 Santa Monica Blvd.	5750 West 51st Street	57 Harper Avenue
Mitchell 2-6165	UPton 0-8807	POrtsmouth 7-3500	TRinity 3-6560

LOG FOR LESS

...$575 to $1100 less with the new NLS 484 digital voltmeter



Here is the only 4-digit voltmeter to provide printer connection and automatic print control for only $2150 . . . the only digital voltmeter at this price to provide heavy duty *plug-in stepping switches,* snap-out readout, and simple single-package design. With plug-in NLS accessories it forms a host of automatic data logging systems. Performance? The 484 retains the basic design and quality construction of the NLS 481, the world's most popular 4-digit voltmeter. Contact NLS for complete information on the 484 if you require ±0.01% accuracy and printout at low cost.

BRIEF SPECIFICATIONS: Accuracy ±0.01% of full scale on each range . . . ranges: ±9.999/99.99/999.9 volts DC, ±99.99/999.9 millivolts DC using NLS 140 Preamplifier, 9.999/99.99/999.9 volts AC using NLS 125B AC/DC Converter . . . input impedance: 10 megohms at balance, 1000 megohms on lowest range by modification . . . automatic range and polarity selection . . . balancing time: 1 sec., average . . . internal standard cell for verification of calibration . . . simple conversion to ratiometer.

Originator of the Digital Voltmeter

non-linear systems, inc. DEL MAR (SAN DIEGO), CALIFORNIA

Extra quality at no extra cost with Bendix Semiconductors

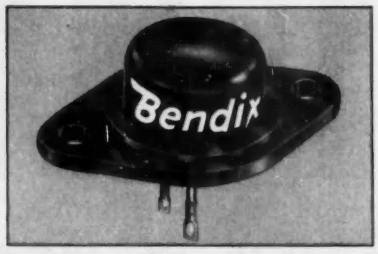
Bendix Bulletin

NEW 25-AMP DAP TRANSISTORS SWITCH IN MICROSECONDS

High Current–Fast Switching–High Voltage —give engineers wider design latitude

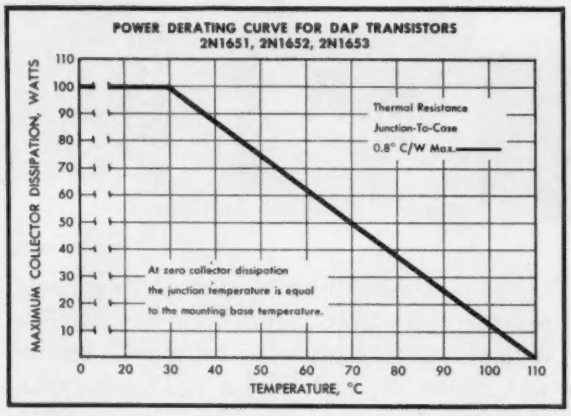
The new 25-amp germanium PNP Bendix® Diffused Alloy Power DAP® transistor line—with its microsecond-fast, higher-current switching (typically 5 μsec at 25 amperes)—frees engineers from the design restrictions set up by ordinary germanium alloy transistors. *Only* Bendix offers such a high-current, high-speed DAP transistor line.

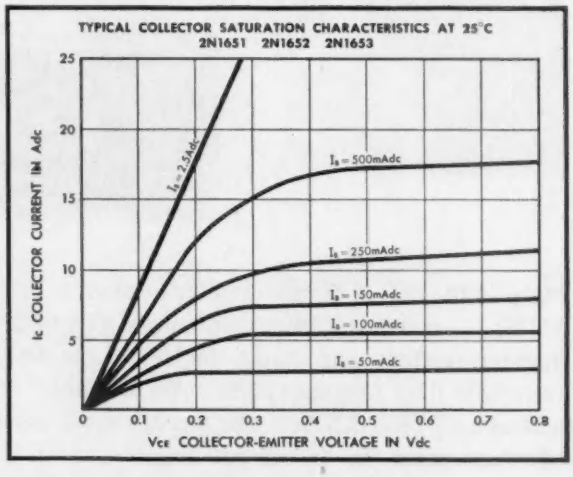
But high current is by no means the whole story. Bendix DAP transistors make possible increased circuit stability over a wider range of temperatures—from −60°C to +110°C. They are also rated at higher collector-to-emitter breakdown voltages, while providing lower input resistance, controlled current gain, and lower saturation voltages. In short, here is a special high-frequency, high-voltage line that opens the door to many new design ideas and applications.



For details on our complete line of power transistors, power rectifiers, and driver and MIL-type transistors, write on your letterhead for your BENDIX SEMICONDUCTOR CATALOG.

ATTENTION ENGINEERS: Write our Employment Manager for information about challenging opportunities we offer in semiconductors.





ABSOLUTE MAXIMUM RATINGS

TYPE NUMBERS	Vce Vdc	Vcb Vdc	Veb Vdc	Ic Adc	Pc W	T Storage °c	Tj °c
2N1651	−60	−60	2.0	25	100	−60 to +110	110
2N1652	−100	−100	2.0	25	100		
2N1653	−120	−120	2.0	25	100		

Ideal for such applications as: ULTRASONICS • HORIZONTAL OUTPUT AMPLIFIERS FOR TV OR CATHODE RAY TUBES • POWER CONVERTERS • HIGH CURRENT AC SWITCHING • CORE DRIVERS • HI-FI

THE Bendix CORPORATION

SEMICONDUCTOR PRODUCTS
Red Bank Division
HOLMDEL, NEW JERSEY

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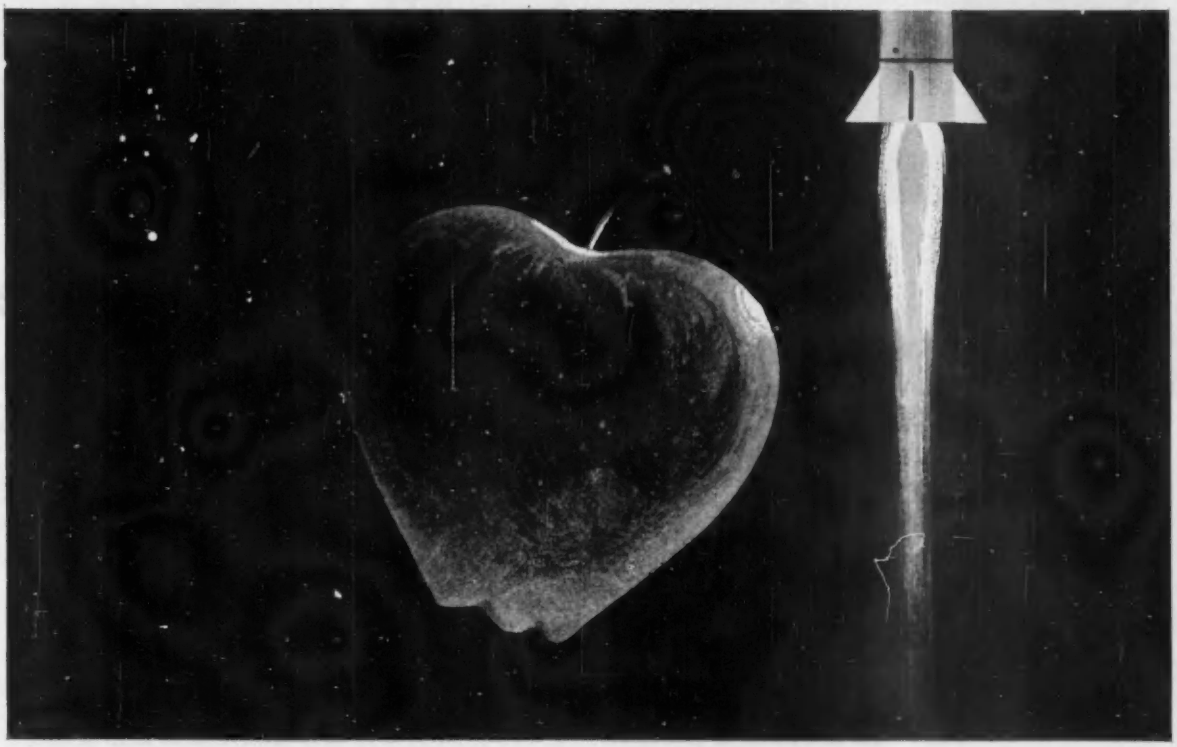
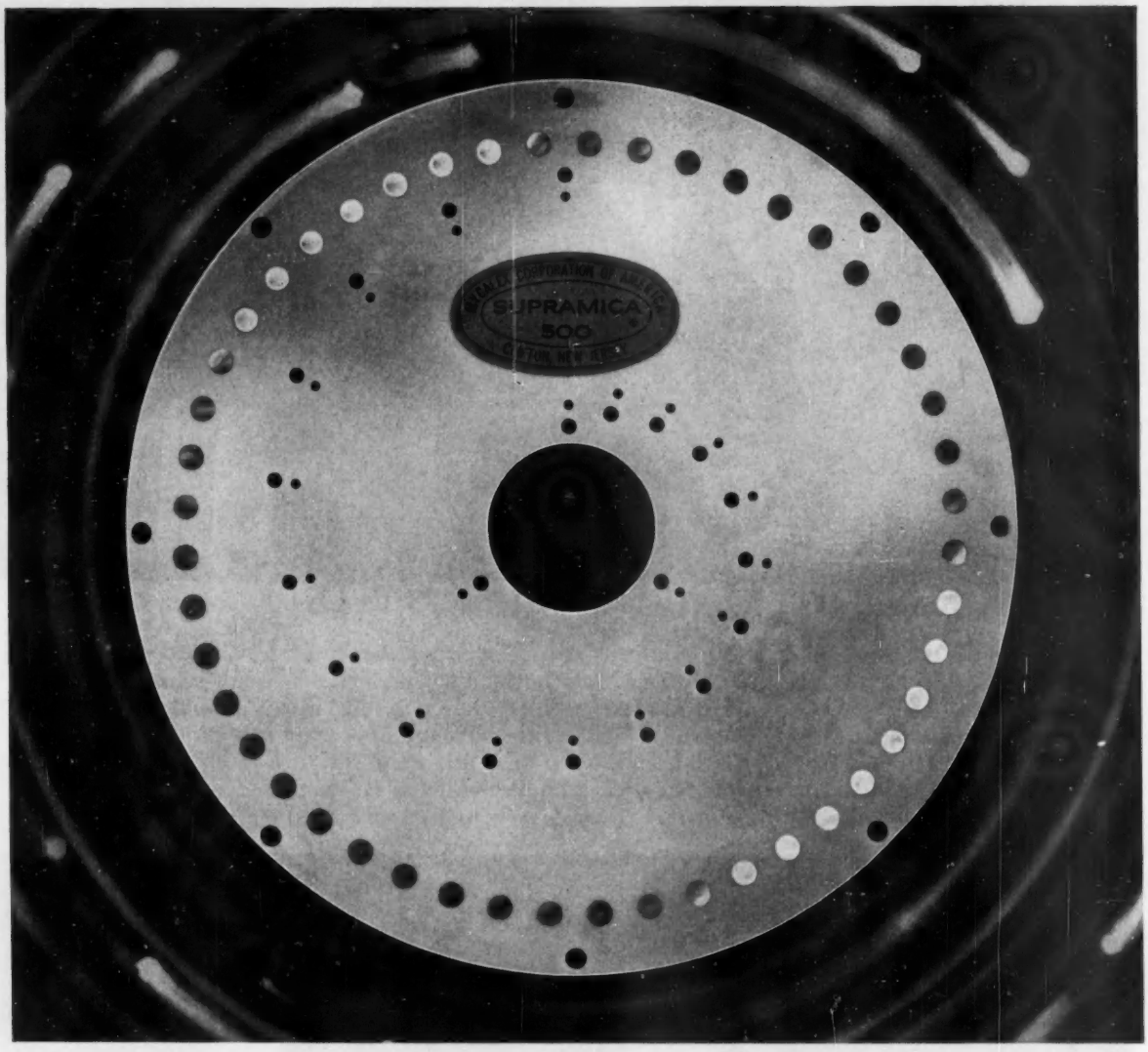
BUT, SIR ISAAC, WE'RE NOT GUIDING APPLES!

Until a ballistic missile is in free fall, our inertial guidance systems must be able to account for both rocket thrust and gravity. Making them this smart is a tough job, but we hit the mark so well on Thor that all of this country's long range missiles will soon be guided inertially. If you would like to help us keep pioneering new guidance systems, and have a BS, MS or PhD in Physics or Math, or an ME or EE, please contact Mr. B. H. Allen, Director of Scientific and Professional Employment, 7929 S. Howell Ave., Milwaukee 1, Wisconsin.

AC SPARK PLUG THE ELECTRONICS DIVISION OF GENERAL MOTORS



When the requirements seem impossible...



48 precious metal contacts on a 12" circle... maintaining .0003 T.I.R. planar tolerance

To SEE under the sea takes a scanning commutator with seemingly impossible tolerances to insure reliability in ship sonar. That is why compression-molded SUPRAMICA® 500 ceramoplastic machinable insulation was chosen . . . a proud example of MYCALEX CORPORATION OF AMERICA craftsmanship.

The specifications are most demanding, the requirements highly critical . . . plates must be flat within .0003" and embody precision-machined recesses to accept 48 pure silver contacts. The angular displacement of the contacts is held to ±1 minute. The combination of contacts and SUPRAMICA 500 together must accept a 2 micro inch surface finish. The application requires that these tolerances are guaranteed for the life of the commutator during which the environmental conditions run the gamut of humidity and temperature.

The MYCALEX fabricating facility is not only fully qualified to furnish the fabrication of such parts but will design and provide required hardware. For gauge-like specifications on large production runs or short prototype quantities . . . our engineers are ready, capable, and equipped to assist you with your design and production requirements. Write for information on SUPRAMICA ceramoplastics offering maximum temperature endurance (unstressed) up to +1550°F. and SYNTHAMICA® synthetic mica with maximum temperature endurance (unstressed) up to +2000°F. . . . the family of the world's most nearly perfect insulation materials.

General Offices and Plant:
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SYNTHAMICA® SUPRAMICA® MYCALEX®
MYCALEX
CORPORATION OF AMERICA

Executive Offices:
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World's largest manufacturer of glass-bonded mica, ceramoplastics and synthetic mica products

NEW FROM POLARAD—
UNIVERSAL SERVO ANALYZER

MEASUREMENT	METHOD OF MEASUREMENT	INPUT TO SERVO SYSTEM	APPLIED TO SCOPE'S VERTICAL PLATES	APPLIED TO SCOPE'S HORIZONTAL PLATES	RESULTING SCOPE PATTERN Typical Response	RESULTING SCOPE PATTERN 0° Phase Shift
PHASE RESPONSE OF A-C SERVO SYSTEMS	Bowtie	50 cps to 6000 cps carrier, modulated at rate of 0.001 cps to 100 cps.	Modulated Return Signal	Low-Frequency Sine Wave		
	Double Bowtie	50 cps to 6000 cps carrier, modulated at rate of 0.001 cps to 100 cps.	Modulated Return Signal	15kc Reference Envelope		
	Sweep	50 cps to 6000 cps carrier, modulated at rate of 0.001 cps to 100 cps.	Modulated Return Signal	Linear Sweep	 Fig. 5-a	 Fig. 5-b
	Sweep	50 cps to 6000 cps carrier, modulated at rate of 0.001 cps to 100 cps.	Demodulated Return Signal	Linear Sweep	 Fig. 5-c	 Fig. 5-d
	Lissajous	50 cps to 6000 cps carrier, modulated at rate of 0.001 cps to 100 cps.	Demodulated Return Signal	Low-Frequency Sine Wave		
PHASE RESPONSE OF D-C SERVO SYSTEMS	Bowtie	Low-Frequency Sine Wave 0.001 cps to 100 cps	Sine Wave Return Signal	15-kc Reference Envelope		
	Double Bowtie	Low-Frequency Sine Wave 0.001 cps to 100 cps	Modulated Wave Return Signal	15-kc Reference Envelope		
TRANSIENT RESPONSE OF A-C SERVOS	Analysis of Returned Square Wave, Triangular Wave, Ramp, or Impulse Functions	Function with Carrier	Modulated or Unmodulated Return Signal	Linear Sweep	 Square Wave  Ramp	 Triangular  Impulse
TRANSIENT RESPONSE OF D-C SERVOS	Analysis of Returned Square Wave, Triangular Wave, Ramp, or Impulse Functions	Function without Carrier	Modulated or Unmodulated Return Signal	Linear Sweep	Same as Figures 5a, 5b, 5c, and 5d, except without carrier. Waveshapes without carrier are indicated by heavy outlines.	
AMPLITUDE RESPONSE OF A-C SERVOS	Oscilloscope Calibration	50 cps to 6000 cps Modulated Carrier	Modulated Return Signal	Linear Sweep (if desired)		
AMPLITUDE RESPONSE OF D-C SERVOS	Oscilloscope Calibration	Low-Frequency Sine Wave	Modulated Return Signal	Linear Sweep (if desired)		

POLARAD ELECTRONICS CORPORATION:
43-20 34th Street, Long Island City 1, N.Y.

Please send me specifications and data on:

POLARAD

MODEL SV-1 SERVO ANALYZER

My application is_____

_____

Name_____ Title_____ Dept._____

Company_____

Address_____

City_____ Zone____ State_____

MAIL THIS COUPON FOR MORE INFORMATION . . .

MODEL SV-1

The new Polarad MODEL SV-1 SERVO ANALYZER is a complete instrument for testing AC and DC servo mechanisms in all applications. It combines a multiple precision signal generator and oscilloscope. Internally generated reference signals are compared with servo outputs and are displayed visually for quick servo analysis.

POLARAD ELECTRONICS CORPORATION

FREE LIFETIME SERVICE

43-20 34th Street, Long Island City 1, N.Y.
Representatives in principal cities.

© P.E.C.

Looking for the newest, most complete line of General Purpose Switches?

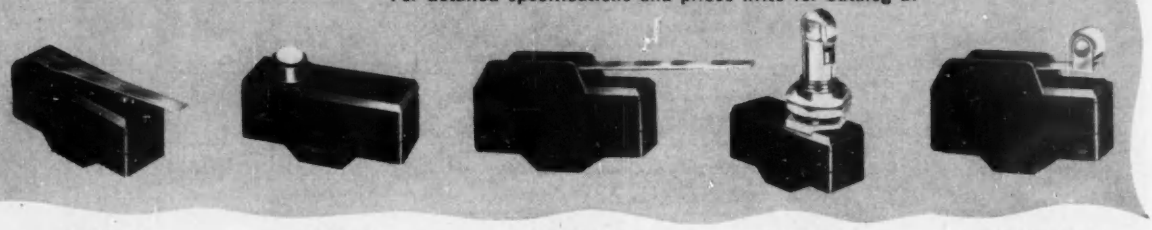
Acro's newly designed model B and F switches will meet your toughest electrical and mechanical requirements

Just check Acro's brand new features!

1. ***NEW!*** Acro's clip-on cover construction, which requires no drilling or pinning, eliminates bakelite dust particles from contaminating the contacts.
2. ***NEW!*** Acro's famous rolling spring principle insures low minimized contact bounce. This gives you high horsepower rating and longer electrical life.
3. ***NEW!*** Up to 21 amp, 2 HP in the F series!
4. ***NEW!*** Moulded-in terminal posts, with blind tap holes, keep out dust and contamination.
5. ***NEW!*** And now Acro offers the most complete line of actuators. Shown are just 10 of the complete series.

model B switches

U.L. Approved 15 AMP 120-240-480 V.A.C. ½ AMP, 120 V.D.C., ¼ AMP, 240 V.D.C.
For detailed specifications and prices write for Catalog B.



BRD2-5L-1S
Leaf Actuator

Operating Characteristics	
Operating force	5 oz. max.
Release force	½ oz. min.
Pretravel	.156 max.
Overtravel	1/32 min.
Movement diff.	.050 max.

BRD2-70-1S
Short Overtravel Plunger

Operating Characteristics	
Operating force	9-13 oz.
Release force	4 oz. min.
Pretravel	.010-.025
Overtravel	1/16 min.
Movement diff.	.003 max.

BRD2-LW8-1S
Overtravel Leaf Actuator (long)

Operating Characteristics	
Operating force	2½ oz. max.
Release force	½ oz. min.
Pretravel	9/32-13/32
Overtravel	.187 min.
Movement diff.	.016-.078

BRD2-24P-1S
Roller Panel Mount

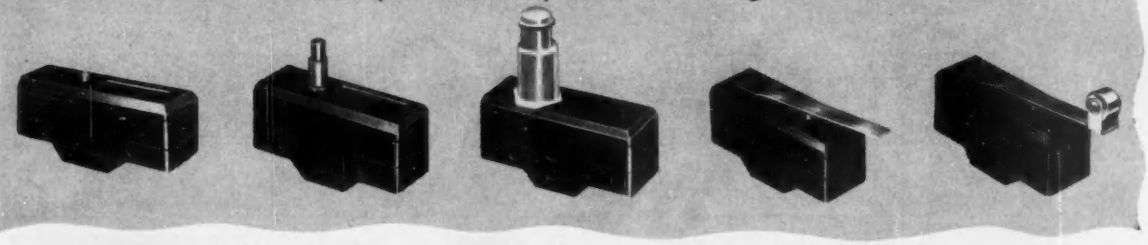
Operating Characteristics	
Operating force	9-13 oz.
Release force	4 oz. min.
Pretravel	.010-.025
Overtravel	.140 min.
Movement diff.	.003 max.

BRD2-LW228-1S
Overtravel Roller Leaf Actuator (short)

Operating Characteristics	
Operating force	6 oz. max.
Release force	1½ oz. min.
Pretravel	.045-.140
Overtravel	.080 min.
Movement diff.	.006-.031

model F

U.L. Approved 21 Amp, 120-240-480 V.A.C., 1 H.P. 120 V.A.C., 2 H.P. 240 V.A.C.
For detailed specifications and prices write for Catalog F



FAD2-1A-1S
Pin Actuator

Operating Characteristics	
Operating force	10-18 oz.
Release force	6 oz. min.
Pretravel	.050 max.
Overtravel	.010 min.
Movement diff.	.0075 max.

FAD2-10-1S
Long Overtravel Plunger

Operating Characteristics	
Operating force	10-18 oz.
Release force	6 oz. min.
Pretravel	.050 max.
Overtravel	1/16 min.
Movement diff.	.0075 max.

FAD2-3P-1S
Large Overtravel Plunger

Operating Characteristics	
Operating force	10-18 oz.
Release force	6 oz. min.
Pretravel	.050 max.
Overtravel	7/32 min.
Movement diff.	.0075 max.

FAD2-5L-1S
Leaf Actuator

Operating Characteristics	
Operating force	9 oz. max.
Release force	1 oz. min.
Pretravel	11/32 max.
Overtravel	1/32 min.
Movement diff.	.065 max.

FAD2-2M-1S
Roller Leaf Actuator

Operating Characteristics	
Operating force	9 oz. max.
Release force	1 oz. min.
Pretravel	11/32 max.
Overtravel	1/32 min.
Movement diff.	.065 max.

for detailed specifications and prices write for catalogs "B" and "F".

Free engineering service. Our engineers will be happy to pit their professional experience against your tough switching problem. Just tell us what it is . . . we'll recommend ways to solve it. No obligation, of course.

RELAYS ACRO SWITCHES

"OUR 21st YEAR"

ACRO DIVISION Robertshaw MR. CONTROLS

COLUMBUS 16, OHIO

GD700 SERIES
GAS-O-DOME REGULATORS

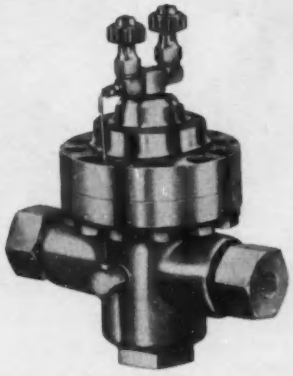
Models in bronze or stainless steel
Pilot operated type
Max. inlet: 7000 to 10,000 psig.
Outlet range: 10-150 to 400-7000 psig.
Flows to 250 scfm.
Low torque: 35 inch-lb. at 7000 psig.
Panel mounting
Bulletins R12 and R18.

BPR SERIES
BACK PRESSURE REGULATORS

Models in bronze or stainless steel
Adjustable relief ranges: From 25-500 psig. to 2000-10,000 psig.
Panel mounting
Bulletin R19

LR SERIES LOADER REGULATORS

Models in bronze or stainless steel
Max. inlet: 7000 to 10,000 psig.
Outlet range: 5-200 to 200-10,000 psig.
Flow: 10 scfm.
Low torque: 35 inch-lb. at 7,000 psig.
60 inch-lb. at 10,000 psig.
Panel mounting
Bulletins R11 and R17

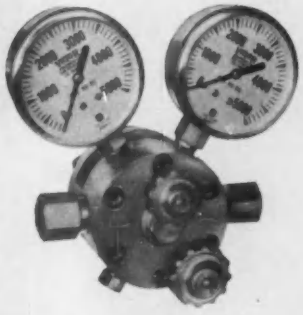


GD90, GD100A AND GD200A
SERIES GAS-O-DOME REGULATORS

Models in bronze or stainless steel
Compensated, high-flow type
Max. inlet and outlet: 6000 psig.
Flows to 80,000 scfm.
Remote control and/or
panel mounting provisions
Bulletin R18

LV-10 LOADER VALVE

Made in bronze only.
Inlet and outlet: 7000 psig.
Flow: 10 scfm.
Fast finger-tip control:
30° clockwise, loads;
30° counter-clockwise, bleeds.
Panel mounting
Bulletin LV-10



GD60 AND 80 SERIES
GAS-O-DOME REGULATORS

Models in bronze
(stainless steel on request)
Inlet and outlet range: 2500 to 10,000 psig.
Flows to 1500 scfm.
Remote control and/or
panel mounting provisions
Bulletin R10A

VICTOR High pressure gas controls

Victor offers you choice of these and many other gas regulators for a wide variety of applications.

All come cleaned for oxygen service; LOX cleaned when specified. Operating temperature ranges: —67° F. to +250° F. (storage —80° F.) Modifications for special applications. Write now for Victor High Pressure Regulator bulletins and Regulator Inquiry Form 361A.

Mfrs. of high pressure and large volume gas regulators; welding & cutting equipment; hardfacing rods; blasting nozzles; cobalt & tungsten castings; straight-line and shape cutting machines.

VICTOR EQUIPMENT COMPANY MISSILE DIVISION 63

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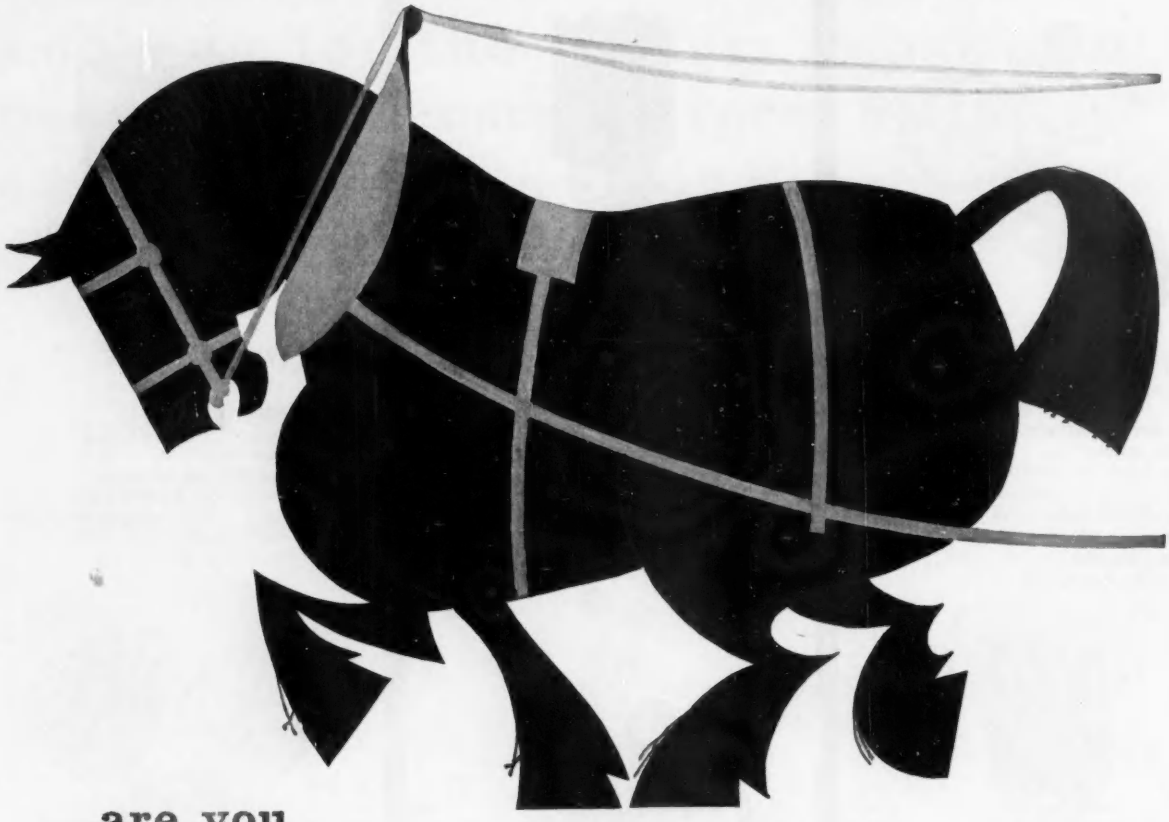
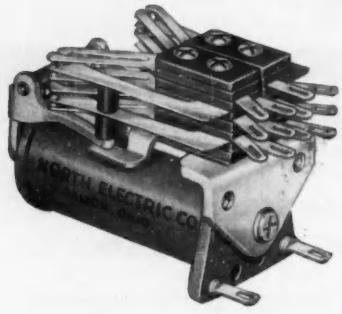
J. C. Menzies & Co., Wholly-Owned Subsidiary

CIRCLE 65 ON READER SERVICE CARD



are you using North Electric's **Workhorse** "E" relay?



Expanded production facilities and increased efficiency in manufacturing methods have enabled North Electric to step up production of "E" relays to provide prompt delivery (at a new low cost, too) to an ever-growing list of steady customers.

If you need a relay that incorporates the inherent proven dependability of a telephone-type relay with minimal spatial requirements, this "little workhorse" from North can be your answer!

GENERAL CHARACTERISTICS:

Light Weight (2½ ozs.)
Compact (Length 2¼"; Width 1⅛"; Height 1¾" max. with 10 springs in either pile-up)
Long Life (over 100 million operations)

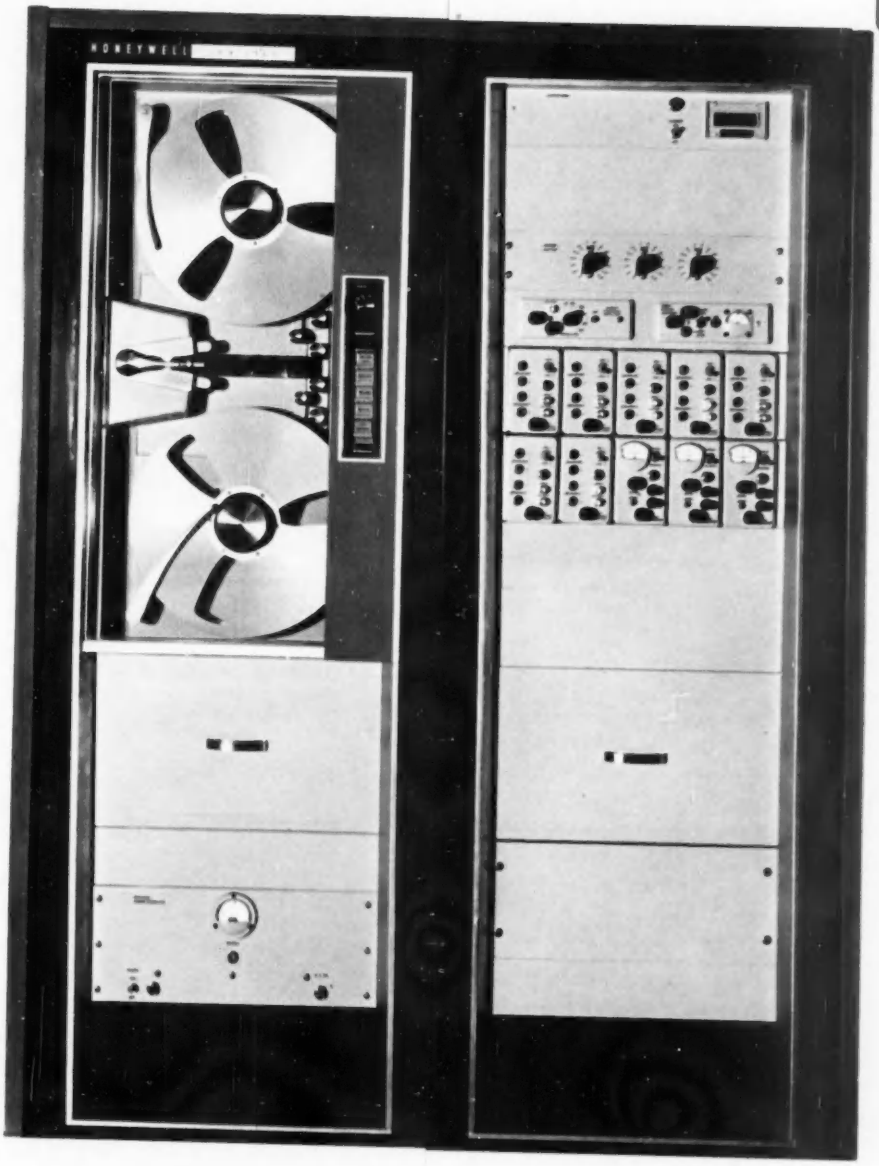
SPECIFICATIONS:

Coil Voltages: Up to 250V DC
Contacts: Independent action twin contact springs
Contact Materials: Palladium, Gold, Platinum
Forms: A to C
Speed: 3 ms. minimum
Residual: Lock Screw (adjustable)—Fixed (nylon flap type)
Time Delay: Available for both operate and release
Coil: Single or Double wound
Mountings: 2 #6-32 Screws on ¾" spacing
Accessories: Dust Cover and Hold Down Bracket

ELECTRONETICS DIVISION

NORTH ELECTRIC COMPANY

6111 S. Market St., Galion, Ohio



INTRODUCING THE NEW

HONEYWELL | **LAR 7500**

MAGNETIC TAPE SYSTEM

- *Eliminates tape breakage!*
- *Records one hour of 10 kc FM data on one reel of tape (±40% deviation)*

INTRODUCING THE NEW

HONEYWELL | **LAR 7500**

MAGNETIC TAPE SYSTEM

New transpo uninterrupte

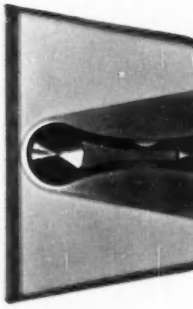
In response to the need f FM data processing system the new LAR 7500 Magn addition to Honeywell's a cording, reproducing and the ground up . . . inco advances.

GENTLE HANDLIN

Mutilation of tape and the is effectively prevented by system and improved *dyn* path reduces edge curl through servo tape tension brakes insure swift, smoo totally eliminate the poss misadjusted friction brake

As a further guarantee hysteresis-synchronous m meter the speed of the tape drive the tape.

The new transport for th functional design, conven ation. Heads and all tape on a single, precision mac



Hinged head cover simplifies to ing. New all metal micro-gap precision lapped . . . reduce Head assemblies plug in to changes in tape width.

sport and electronics assure accurate, pted record of a long data run

eed for more efficient and reliable ystems, Honeywell proudly presents Magnetic Tape System. This latest ell's already broad line of data re- and reducing systems is new from incorporates a host of technical

LING PROTECTS TAPE— d the resultant loss of valuable data ed by use of a unique edge guiding l *dynamic braking*. The tape guide curl and minimizes skew. Acting nsion control circuits, the dynamic smooth stops from all speeds and possibility of tape damage due to brakes.

tee of precise tape handling, the us motor-driven capstan serves to e tape across the heads—it does not

or the LAR 7500 embodies clean, nvenience, and safe, efficient oper- tape guiding elements are mounted machined, ribbed subcasting. The transport glides smoothly from the rack for easy access to both sides. Backlighted push-buttons control and indicate operating modes. Controls are interlocked to eliminate accidental loss of data.

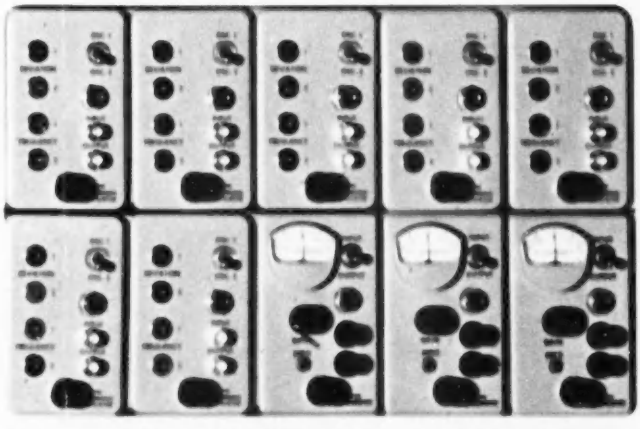
It is this unique combination of features that eliminates the possibility of tape breakage with Honeywell LAR 7500 Systems.

DATA CAPACITY DOUBLED BY NEW ELECTRONICS—The ability to record over an hour of 10 kc data (or ½ hour of 20 kc data) with ±40% deviation on one reel of tape can often eliminate the need for a second transport to get an uninterrupted record of test results. In every case, you halve tape consumption by using an LAR 7500 System instead of a conventional system. Of course, the LAR 7500 is compatible with existing systems.

The all-transistorized components make it possible to put a complete 14 channel FM record and playback system into one rack. The discriminator output of 75 milliamps is sufficient to drive any *Visicorder* galvanometer.

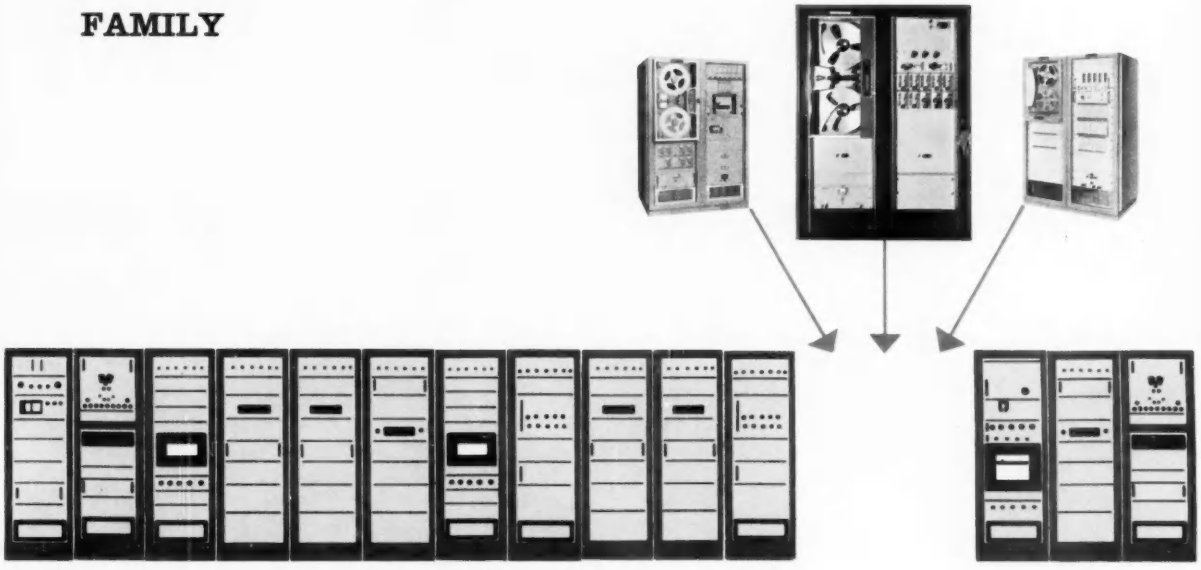
The LAR 7500 offers the advantages of wide bandwidth recording at low tape speeds at a truly moderate price . . . another example of Honeywell's ability to tailor a system to your technical requirements and your budget.

ifies tape thread- o-gap heads are duce tape wear. in to facilitate



Compact, transistorized FM components have all necessary controls conveniently located in front.

THE HONEYWELL LAR 7500 TAPE SYSTEM JOINS A VERSATILE FAMILY



Honeywell data systems are custom-designed to give you—quickly and accurately—the information you need, in the form you want it, for any scientific, military or industrial application.

The LAR 7500 adds important new refinements to an already versatile line of tape instrumentation. Like other Honeywell systems, it can be expanded to perform a host of related functions with the addition of such equipment as automatic wave analyzers, *Visicorder* direct-reading oscillographs and format conversion systems. All components are designed and manufactured by Honeywell, and complement each other perfectly. Assembled with standard modules, these systems can be readily altered or enlarged to meet your changing requirements.

Ask your nearby Honeywell field engineer, from one of 125 sales and service offices in the U.S. and Canada, for expert assistance in planning the data system that can serve you best.

For complete literature and specifications, write to:

MINNEAPOLIS-HONEYWELL, Industrial Systems Division, 10721 Hanna Street, Beltsville, Maryland.

Honeywell

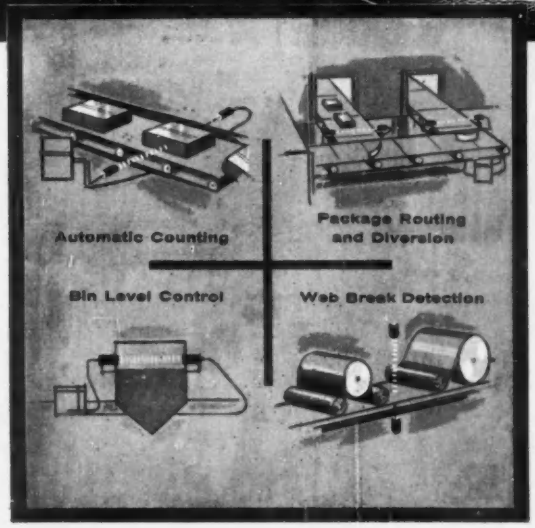
First in Control

SINCE 1885

75th YEAR

PIONEERING THE FUTURE

a new dimension in automated controls



SONAC ULTRASONIC,

NON-CONTACT SENSING AND SWITCHING SYSTEM

Before Sonac, sensing and switching control systems which involved breaking a beam of energy were limited by vibration, dust, smoke, steam, air contamination and too much or too little light. Sonac's ultrasonic energy "beam" is completely free of these limitations. The acoustic lens on Sonac sensors can actually be painted without affecting performance. Utilizing high frequency sound also means there are no lamps to burn out. Savings in replacement parts and maintenance time often means Sonac pays for itself. Sonac is completely transistorized, providing you with a rugged, dependable electronic circuit.

These are just a few of Sonac's many uses. Optional equipment includes reflectors for precision beam and positioning control, and coupler assemblies for use with flexible tubing for remote sensor locations. This descriptive booklet will be sent to you on request.

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CIRCLE 71 ON READER SERVICE CARD 71

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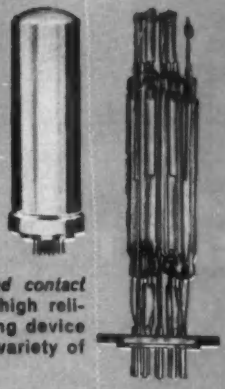
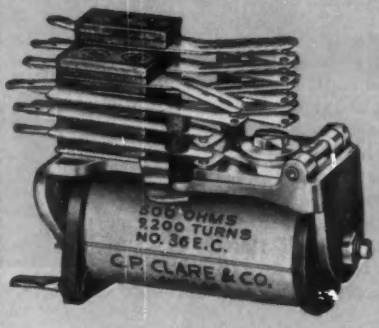
Type F relay—small, sealed, postage-stamp sized relay with unusual flexibility for long-life operation.



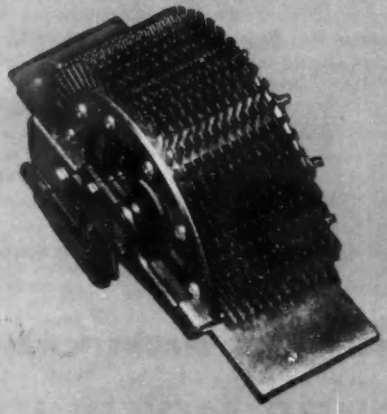
CLAREED sealed contact reed relay—A high reliability switching device available in a variety of packages.

for immediate delivery at factory prices



Type J relay—a compact telephone-type relay of unequalled long life and superior performance.

Mercury-wetted contact relay capable of billions of extremely fast operations with no maintenance.



Stepping switches—a full line with capacities from 10 to 52 points and capable of millions of steps without readjustment.

Here's what this new CLARE service means to you:

Top quality—the same fine design and long life you get in CLARE custom-built relays and switches

Fast service—overnight delivery on many items

Easy purchasing—because you can order CLARE devices along with other components

Able engineering assistance—available through CLARE field engineers, working in close cooperation with CLARE distributors.

When *standard* CLARE relays or switches meet your needs, distributor service saves you time, costs no more. When your special needs require custom design and production, CLARE *custom-built devices* give you exactly what you require.

C. P. Clare & Co., 3101 Pratt Blvd., Chicago 45, Illinois. In Canada: C. P. Clare Canada Ltd., P.O. Box 134, Downsview, Ontario. Cable Address: CLARELAY

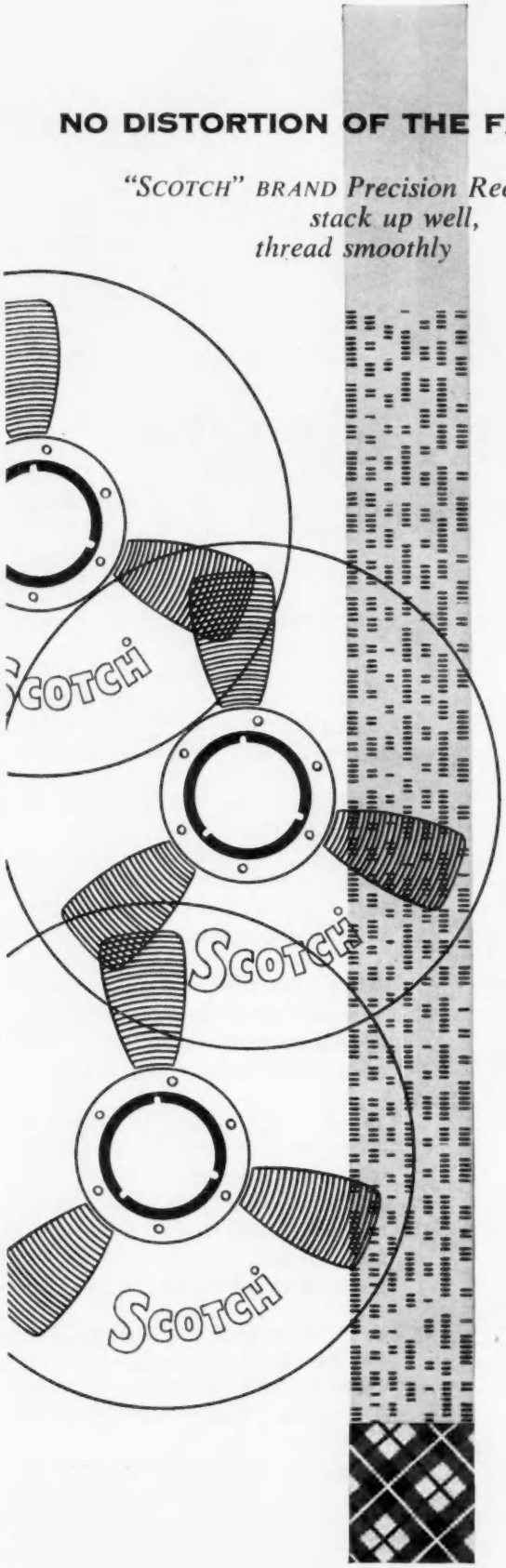
CIRCLE 73 ON READER SERVICE CARD

CLARE

Relays and Related Control Components

NO DISTORTION OF THE FACTS

"SCOTCH" BRAND Precision Reels stack up well, thread smoothly



IN INSTRUMENTATION, it nearly goes without saying that your choice of reels is as important as your choice of magnetic tapes. You can't afford any distortion of the facts you deal with—so why not give your "SCOTCH" BRAND Tape the best running mate—a "SCOTCH" BRAND Precision Reel.

While most drop outs come from dust or other contaminants on the tape surface, the next most significant factor is related to improper handling. Dents or creases in the tape backing, damage to tape edges caused by uneven winding, too much tension on the tape at the end of a pass—all of these affect performance. Any stresses which exceed the yield point of the tape can cause a permanent set—a physical distortion which in turn leads to the attenuation or loss of important signals.

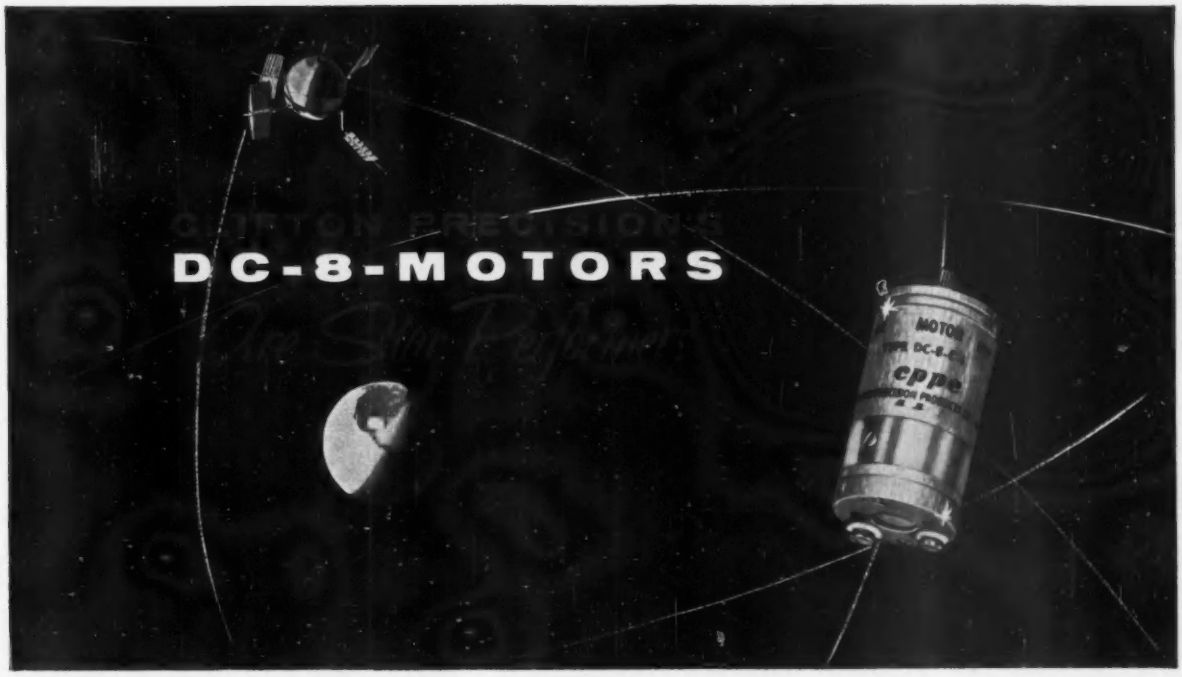
Precision is no empty word when applied to the "SCOTCH" BRAND reel. Every detail—design, materials and production techniques – grows out of years of careful research and testing by the same 3M research teams who have continually led in the development of magnetic tapes.

The "SCOTCH" BRAND Precision Reel is machined of aluminum. Its unique design offers maximum protection against tape damage from handling, while greatly lowering the moment of inertia—exerting less stress in stops and starts. Because the flanges are precision machined, they can be held to a fine tolerance—thicker at the hub, thinner toward the rim. These closely spaced, tapered flanges guide the tape into a smooth, even stack. Tape edges are kept perfectly aligned.

Threading up is easy on you and the tape. The "SCOTCH" BRAND reel employs a precision ground neoprene ring instead of a threading slot which can cause distortion of the inner turns of tape. To thread up, you simply start a turn of tape on the take-up reel. The neoprene ring, moreover, acts as a cushion for the innermost tape layers and guards against distortion from winding pressure and expansion-contraction stresses.

Flange apertures are reduced to the minimum compatible with the need for observation and threading—giving further protection to tape and greater rigidity to the reel. Compare—as the moment of reel decision approaches, a look at all the facts should lead you to come out in favor of "SCOTCH" BRAND Precision Reels.

Your 3M Representative is close at hand in all major cities—a convenient source of supply and information. For details on reels and tape constructions, consult him or write Magnetic Products Division, 3M Co., St. Paul 6, Minnesota.



500 HOUR LIFE GUARANTEE*

Due largely to improved brush design, CPPC size 8 DC motors qualify to catalogue specification after 500 + hours of continuous duty or 200,000 cycles of intermittent duty in controlled environments.

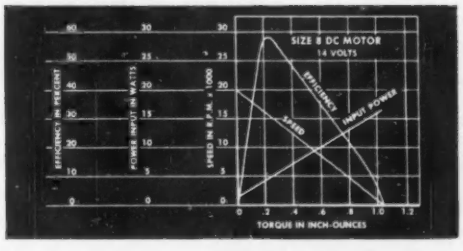
PRECISION CONSTRUCTION

Featuring a 12-bar commutator (1/4" dia.), stainless steel ball bearings, and corrosion resistant materials, the DC-8 family of motors is designed for miniature instrument systems. Weight 40 gms., Length 1.380" max., dia., .750".

OUTSTANDING EFFICIENCY

The typical performance curves (below) exhibit a linear torque-speed characteristic. The efficiency—up to 60% at .25 in. oz. torque—considerably surpasses that of other types of Servomotors.

*without overhaul



For full information, write or call: Sales Dept., 5050 State Road, Drexel Hill, Pa., MAdison 2-1000, TWX Lnsdwn, Pa., 1122(U), or our Representatives.

cppc

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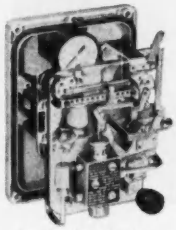
CLIFTON HEIGHTS, PA.

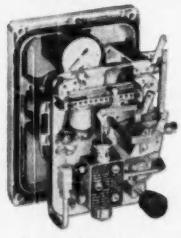
ENGINEERS—Join a pioneer in the rotary components field. Write David D. Brown, Director of Personnel.

Recording Unit for Variable 1

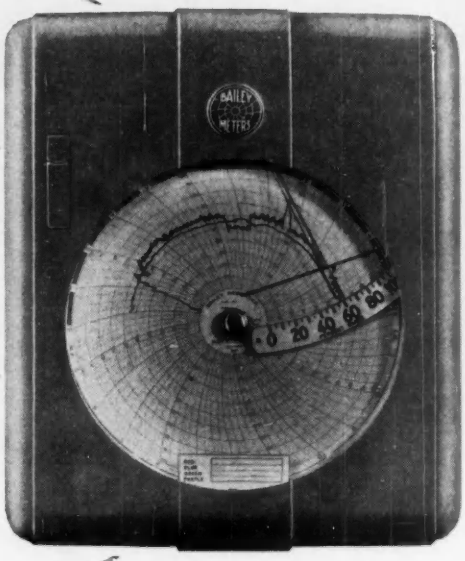
Recording Unit for Variable 2



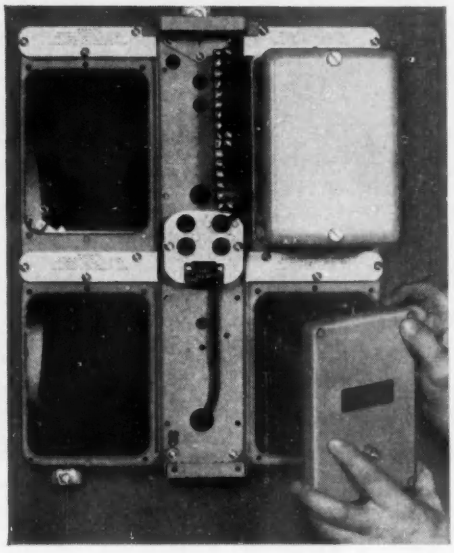
Controlling Unit for Variable 1



Controlling Unit for Variable 2



Back of Bailey Recorder, showing how four plug-in units may be added as needed.



Key to "step-by-step" automation . . .

BAILEY RECORDERS

with plug-in flexibility

When you are pioneering a new process and don't know all the answers, complete automation is seldom practical. The first step is to identify your variables and measure them. Nothing does this job better than a Bailey Recorder. One instrument can record any four variables that can be converted to electric *or* pneumatic signals.

Then you will want to add controls and feed back your measurements. Here's where the versatility of the Bailey Recorder comes into play. For the same Bailey instrument you use to record variables is designed to accommodate plug-in control units.

When you use a Bailey Recorder, you can build your instrumentation along with your process. At the start, you use only the plug-in units for recording. Then you add plug-in controls as you see the need for them.

For the complete story of how you can use a Bailey Recorder for step-by-step automation, contact your local Bailey Engineer.

G154-1

Instruments and controls for power and process

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Polaris missile submarines use the Kollmorgen-designed and built Type 11 periscope—the world's largest—for pinpoint fixes by celestial navigation. Reference stars are programmed into the sub's stabilization computer in advance as celestial navigation coordinates. The Type 11 periscope then trains on a reference star, with adjustment by the operator as necessary, and feeds an error signal back through to the ship's inertial navigation system, which is automatically corrected. The precise position data necessary for optimum execution of the submarine's mission is thus assured.

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NEW! CONTROLLED

4 TRANSITRON TYPES AUGMENT

Silicon Controlled Rectifiers / Switches

NEW! CONTROLLED SWITCHES

TSW31S - TSW201S PNPN bistable switching devices in TO-18 packages, with maximum holding current of 1 ma.

- High gate sensitivity 20 μa to fire
- Covers current range from 1 ma to 200 ma @ 75°C ambient
- Voltage ratings up to 200 volts available
- Temperature range: −65°C to +150°C

CIRCLE 244 ON READER SERVICE CARD

NEW! TO-5 PACKAGE CONTROLLED RECTIFIERS

Two series of diffused silicon PNPN bistable switching devices with very low triggering requirements and micro-second switching.

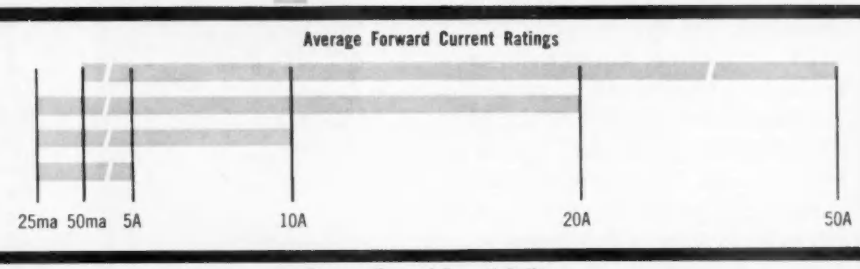
TCR251-TCR4001 series featuring:

- Low leakage: 100 μA @ 125°C case
- High gate sensitivity: 200 μA @ 25°C
- Low Holding Current: 5 mA maximum @ 25°C
- Current rating: 1 amp at 80°C case or 600 ma at 25°C ambient
- Voltage ratings: Up to 400 volts

Plus **2N1595-2N1599** series with same current and voltage ratings

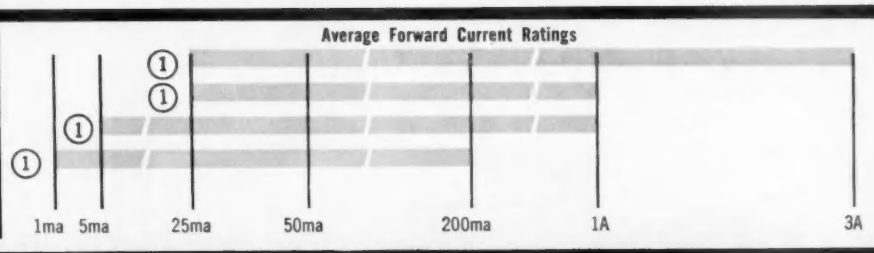
CIRCLE 245 ON READER SERVICE CARD

Series	Package
TCR 550	1⅛ hex base
TCR 520	11/16 hex base
TCR 510	11/16 hex base
TCR 505	⅞ hex base



2N1600	⅞ hex base
2N1595	TO-5
TCR 251	TO-5
TSW 31S	TO-18

① Maximum Holding Current Values



The complete Transitron line of Controlled Rectifiers and Controlled Switches includes the following higher current types:

NEW! 2N1600-2N1604 and TCR505-TCR4005 series diffused Silicon Controlled Rectifiers

- Current ratings: 3 amps at 80°C case; 1 amp @ 125°C case
- Voltage ratings: Up to 400 volts
- Package: ⅞" hex base

CIRCLE 246 ON READER SERVICE CARD

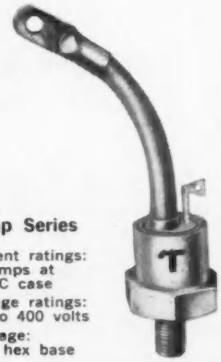
10 Amp Series

- Current ratings: 10 amps @ 25°C case; 5 amps at 100°C case
- Voltage ratings: Up to 400 volts
- Package: 1¼" hex base

20 Amp Series

- Current ratings: 20 amps @ 25°C case; 10 amps at 100°C case
- Voltage ratings: Up to 400 volts
- Package: 1¼" hex base

CIRCLE 247 ON READER SERVICE CARD



NEW!

50 Amp Series

- Current ratings: 50 amps at 100°C case
- Voltage ratings: Up to 400 volts
- Package: 1⅛" hex base

CIRCLE 248 ON READER SERVICE CARD

RECTIFIERS & SWITCHES

INDUSTRY'S BROADEST LINE!

Binistors / Transwitches

THE BINISTOR

(bý-nis-tor)

Transitron's new silicon NPN Tetrode offers simpler, more reliable, more economical switching and storage circuitry. The key parameters of this bistable, negative resistance device are determined by external circuitry, providing remarkable stability and uniformity over wide temperature ranges. The signal and output swings are compatible with present transistor and diode circuits. Two series are available: The wide temperature range or military types and the commercial and industrial computer types. The stability and uniformity of each unit in the military series is absolutely guaranteed by the method of specification at critical temperatures (−65°C and +150°C).

CIRCLE 249 ON READER SERVICE CARD

ABSOLUTE MAXIMUM RATINGS

	3N56	3N57
Collector to Emitter Voltage (V_{CE})	15 Volts	15 Volts
Collector Current @ 25°C (I_C)	30 mA	30 mA
Storage & Operating Ambient Temp. Range	−65°C to +150°C	−55°C to +100°C

3N56 MILITARY TYPE
SPECIFICATIONS & TYPICAL CHARACTERISTICS (At Noted Ambient Temp.)

TURN-ON	AMBIENT TEMP	MIN.	TYPICAL	MAX.	TEST CONDITIONS
D.C. Collector Saturation Voltage (V_{CE})	−65°C	—	0.46	1.0 V	I_C = 10mA, I_b = + .5mA*
	+25°C	—	0.7	1.0 V	V_J = 4V, R_J = 3K
	+150°C	—	1.2	1.5 V	supply
Critical Injector Current ($I_{J\ crit}$)	−65°C	0	.38	.5 mA	I_C = 10mA, I_b = − 50μa
	+25°C	0	.28	.5 mA	
	+150°C	0	.21	.5 mA	
	−65°C	0	1.10	1.5 mA	I_C = 0.25mA, I_b = − 50μa
	+25°C	0	0.86	1.5 mA	
	+150°C	0	0.40	1.5 mA	
TURN-OFF Base Cutoff Current (I_{bo})	−65°C	—	—	—	V_{CE} = 15 volts, V_{JE} = + 13 volts
	+25°C	—	.020	.2 μA	V_{BE} = − .6 volts
	+150°C	—	2.0	10.0 μA	

3N57 COMPUTER TYPE
SPECIFICATIONS & TYPICAL CHARACTERISTICS @ 25°C

TURN-ON	MIN.	TYPICAL	MAX.	TEST CONDITIONS
D.C. Collector Saturation Voltage (V_{CE})	—	0.7	1.0 V	I_C = 10mA, I_b = + .5mA* V_J = 4V, R_J = 3K supply
Critical Injector Current ($I_{J\ crit}$)	0	.28	0.5 mA	I_C = 10mA, I_b = − 50μa
	0	.86	1.5 mA	I_C = 0.25mA, I_b = − 50μa
TURN-OFF Base Cutoff Current (I_{bo})	—	.020	.2 μA	V_{CE} = 15 volts, V_{JE} = + 13 volts V_{BE} = − .6 volts

*Unit must switch on under the above conditions; however, actual V_{CE} measurement is made with I_b = − 50μa

THE TRANSWITCH

A PNPN bistable silicon computer element that can be turned on and off with gate current. The device is available in the TO-18 package, and is designed for miniaturized memory circuits, ring counters, shift registers, controlled rectifier drivers, and flip flop equivalents. A 100 ma series (TSW-31A-TSW-201A) has been added to the Transwitch series. Both series (50mA and 100mA) are available in voltage ratings up to 200 volts. For commercial and industrial applications, the SW-30 type is now available. This unit, especially designed for lower temperature applications, features maximum collector current rating of 30mA and maximum voltage rating 30 volts.

CIRCLE 250 ON READER SERVICE CARD

ABSOLUTE MAXIMUM RATINGS

	SW-30	TSW-31 thru TSW-201	TSW-31A thru TSW-201A
Forward current I_f	30 mA	50 mA	100 mA
Operating temp. range	−55°C to +85°C	−55°C to +125°C	−55°C to +125°C

SPECIFICATIONS (AT 25°C)

	SW-30	TSW-31 thru TSW-201	TSW-31A thru TSW-201A
Max. Saturation Voltage (V_S)	1.5 V @ 30 mA	1.5 V @ 50 mA	2 V @ 100 mA
Max. Forward "OFF" Current (I_{CEO})	10 μA	10 μA	10 μA
Max. Reverse Current (I_R)	10 μA	10 μA	10 μA
Max. Forward "OFF" Current (I_{CEO})	50 μA @ 85°C	50 μA @ 125°C	50 μA @ 125°C
Max. Reverse Current (I_R)	50 μA @ 85°C	50 μA @ 125°C	50 μA @ 125°C
Max. Gate Voltage to Switch "ON" ($V_{G\ ON}$)	1.0 V	1.0 V	1.0 V
Max. Gate Current to Switch "ON" ($I_{G\ ON}$)	1.5 mA	1.0 mA	1.0 mA
Max. Gate Voltage to Switch "OFF" ($V_{G\ OFF}$)	−5.0 V	−4.0 V	−6 V
Max. Gate Current to Switch "OFF" ($I_{G\ OFF}$)	−8.0 mA	−10 mA	−20 mA
Max. Holding Current (I_H)	10.0 mA	5.0 mA	7.0 mA

In writing for further information on all these devices, refer to the following bulletin numbers:

Controlled Rectifiers & Switches		Binistor & Transwitch	
TSW-31S series	Bulletin # TE-1356E	TSW-31A	Bulletin # TE-1357B-1
TCR-251 series	Bulletin # TE-1356D		
2N1595 series	Bulletin # TE-1356C	TSW-31	Bulletin # TE-1357B
2N1600 series	Bulletin # TE-1356B-1		
TCR-505 series	Bulletin # TE-1356B	SW-30	Bulletin # TE-1357E
10 amp series	Bulletin # TE-1356A-1	3N56	Bulletin # TE-1360A
20 amp series	Bulletin # TE-1356A		
50 amp series	Bulletin # TE-1356AA	3N57	Bulletin # TE-1360B

Transitron electronic corporation
wakefield, melrose, boston, mass.

"Leadership in Semiconductors"

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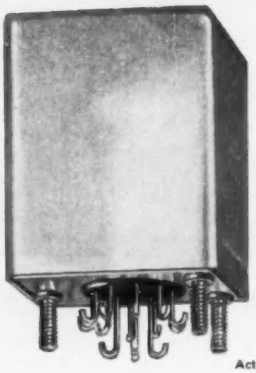
"Shock Troop" Performance

...withstands 10g 500 cycle vibration

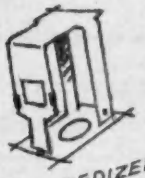


Actual Size

RBM MINIATURE HERMETICALLY SEALED RELAYS

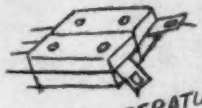
The reliability of this relay under severe conditions of vibration and shock has been field-proven in many applications. It is another example of how R-B-M's production maturity and complete facilities can eliminate many of your engineering problems.

BHSM AND BHSM-HT TYPES HAVE THESE FEATURES



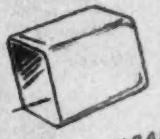
"RUGGEDIZED" WELDED RELAY AND BRACKET ASSEMBLY

DEPENDABLE X-BAR CONTACTS



HIGH TEMPERATURE PILE UP INSULATORS (HT VERSION)

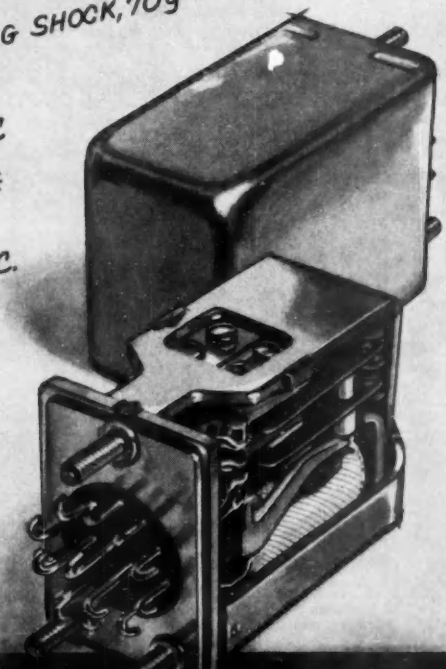
KEL-F COIL BOBBIN AND CLASS H MAGNET WIRE (HT VERSION)



HERMETICALLY SEALED OR DUST COVER AVAILABLE

OPERATING BENEFITS

- 125°C OPERATING AMBIENT
- TEMP. RANGE } 22700 BHSM TYPE, -55°TO+85°C 22800 BHSM HT TYPE, -65°TO+125°C
- COIL UP TO 130 V.D.C. } SENSITIVITY 0.2 W. MIN. PER POLE MAX. COIL DISSIPATION 3.75 W.
- CONTACTS-MAX. 4 PDT 3 AMP. AT 32 V.D.C. OR 115 V.A.C. (NON-INDUCTIVE)
- SPECIAL CONTACTS AVAILABLE FOR LOW LEVEL OR DRY CIRCUIT APPLICATIONS
- APPROX. WEIGHT - 3.25 OZ.
- 30g OPERATING SHOCK, 70g NON-DESTRUCTIVE



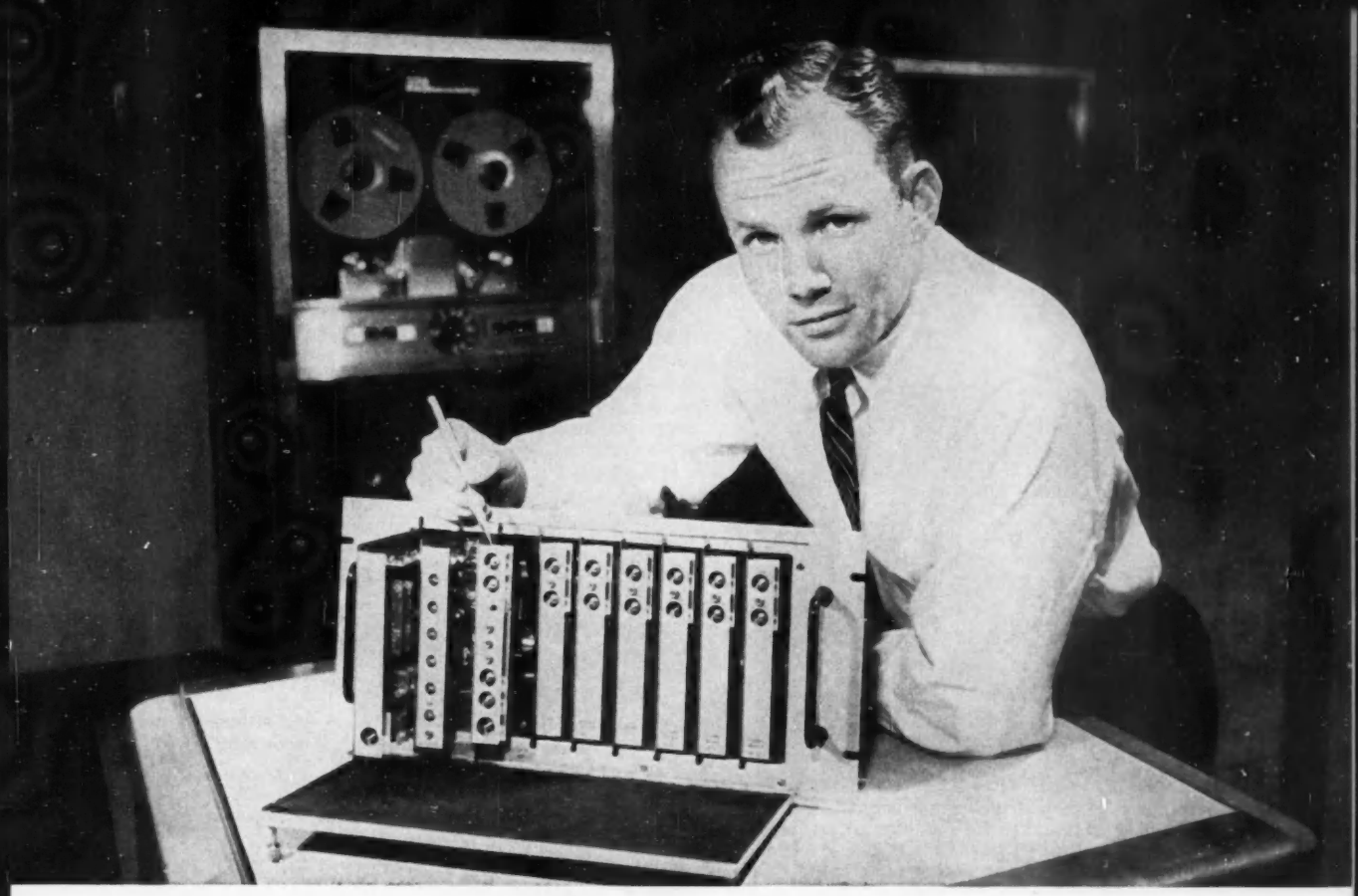
Consult your local RBM Product Application Engineer or write for Bulletin BHSM-1.

"Controlling the Future"

RBM Controls Division

ESSEX WIRE CORPORATION, LOGANSPORT, INDIANA

Factories Located at North Manchester and Logansport, Indiana



Raytheon's Revolutionary A-D Converter Handles 5 Million Samples/Second

It is 100 times faster than any other available . . . about the size of an office typewriter . . . offers Industry and the Military a basic, solid state tool compatible with the speeds of newer electronic systems.

It can, with modification, scramble video signals . . . or ride inside a satellite or missile, converting temperature and other environment data.

Its applications encompass almost any product or process requiring continuous, automatic control of a constantly varying multiphase system.

Equipment employing this technique can digitize target information faster, enabling radar control systems to intercept or guide missiles or aircraft more accurately . . . help analyze an oil refining process, or the trajectory of an ICBM, in millionths of a second.

It is the most recent example of Raytheon Company Communications-Data Processing Capability.

Mail Coupon Today For Folder & Specifications

DIRECTOR OF MARKETING,
Equipment Division,
Department E-2, Raytheon Company,
West Newton, Massachusetts

Please mail me further information on new 7-bit binary code A-D Converter. I am currently concerned with:

_____

_____

_____

_____

(type of system)

*Name and Title*_____

*Company*_____

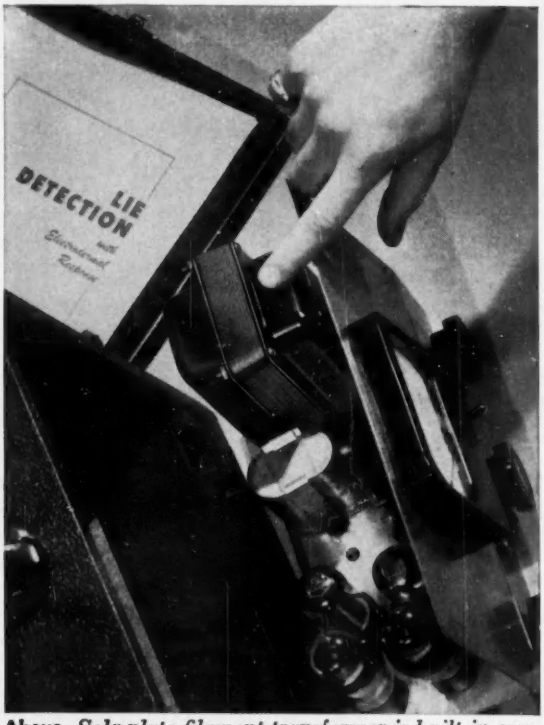
*Address*_____

*City & State*_____

RAYTHEON EQUIPMENT DIVISION

EXCELLENCE IN ELECTRONICS

CIRCLE 81 ON READER SERVICE CARD



Above—*Sola plate-filament transformer is built-in component of B & W Associates lie detector. It supplies plate and filament voltage regulated within ±3% even when line voltage varies from 100 to 130 volts . . . helps assure accurate operation in field.*

Below—*Railway Communications Inc. uses Sola line voltage regulator to improve performance and reliability of this Rycom combination transmitter-receiver. Regulator delivers 118 volts stabilized within ±1% under line voltage variations as great as ±15%.*

Build it in or add it on . . . Sola voltage regulation helps your equipment give full-rated performance

Whether you build it in as a component or add it on as an accessory, a Sola static-magnetic voltage regulator soon pays for itself by keeping your equipment operating at its designed capability.

These units provide a stabilized output voltage even when input voltage varies over a considerable range, and give you eight important advantages over electronic or motor-driven regulators:

1. **Ultra-fast response time of 1.5 cycles or less reduces effects of transients.**
2. **No moving or renewable parts or routine maintenance.**
3. **Automatic, continuous regulation; no manual adjustments.**
4. **Protection against accidental short circuits and excessive overloads for unit and its load.**
5. **Versatility: Step-up, step-down, plate, plate-filament, transistor-voltage ratios are available to permit substitution in place of non-regulating transformers.**
6. **Simple, compact design; light weight.**
7. **High degree of isolation between input and output circuits.**
8. **Negligible external magnetic field.**

This is the Sola Standard Sinusoidal Constant Voltage Transformer, shown in its usual accessory-type structure. It continuously regulates output voltage within ±1% under line voltage variations of ±15%. Because its output is essentially a commercial sine wave (less than 3% total rms harmonic content at any load above 25% of rating), it is ideal for exacting laboratory applications and instrument calibration, and with equipment sensitive to wave shape . . . designed d-c voltage levels in the load are not affected.

The entire line of sinusoidal regulators is now available at prices formerly charged for static-magnetic regulators without the patented Sola harmonic-free circuit.

This is the Sola Normal-Harmonic Constant Voltage Transformer, shown in component-type structure, with end bells and separate capacitor. It offers the same reliability and ±1% regulation as Type CVS (above), and is suitable for the many applications where a commercial sine wave voltage supply is not required. It is widely used for voltage regulation on filaments, solenoids and relays.

Because prices of these normal-harmonic units have been substantially reduced, voltage regulation may now be possible in many of your applications.

Sola static-magnetic voltage regulators are available in a wide selection of mechanical structures and ratings in over 40 stock models, and your custom designs can be delivered in production quantities.

Write for Bulletin 26L-CV

SOLA

SOLA ELECTRIC CO.
Busse Rd., at Lunt,

BPC

A Division of Basic Products Corporation
Elk Grove, Illinois

CHECKUP on your Control Valves... CHECKOFF these Annin Advantages*

*Any other source might give you a few... but with Annin you get them all!

MINIMUM number of parts per complete valve.

OVER 60,000 successful case histories of split body valve applications.

POSITIONING ACCURACY guaranteed, .001 inch per inch of stroke.

CONSTANT INSTRUMENT signal sensitivity throughout signal range.

COMPLETE INTERCHANGEABILITY of any Domotor valve to on-off pneumatic control, pneumatic hydraulic, electro hydraulic, electro pneumatic or manual actuator.

ENGINEERED FOR MANUAL control with any of the above automatic actuators, if desired, at minimum cost.

SIMPLIFIED ADDITION of high speed booster units to any pneumatic positioning actuator.

ADAPTABILITY of bellows seal, doolseal or plain extension to any standard valve.

BODY SIZES from ¼" up.

COMPLETE LINE of body ratings: 600—1500—2500 lbs. ASA; special 10,000 and 60,000 psig design, temp. —450°F to 1600°F.

CONVERSION FROM globe body to angle body construction with only one additional part.

ADAPTABILITY TO 3-WAY Valve Construction with minimum parts and cost.

MINIMUM COST for change from soft seat construction to hard seat, or vice versa.

First in a series of checklists on Annin features.

Annin VALVES

THE ANNIN COMPANY
1040 South Vail Avenue
Montebello, California

ACCURATE Remote Measurement of DISPLACEMENT or LIQUID LEVEL distances up to 1000 feet

Plug this portable, self contained unit into any 110 volt, 60 cps outlet. This is *all you need* to accurately measure any displacements in ranges from ½ inch to 10 feet; from any distance up to 1000 feet. The system is built on the null balance principle. Since it contains no vacuum tubes, it is capable of operation for years without re-calibration or loss of accuracy.

FEATURES

Stroke: ½" up to 10 feet.

Accuracy: ± .3%.

Recording: Provides D.C. output for control and for recording displacements down to .0005 inch.

Package: Self contained; no added instrumentation required.

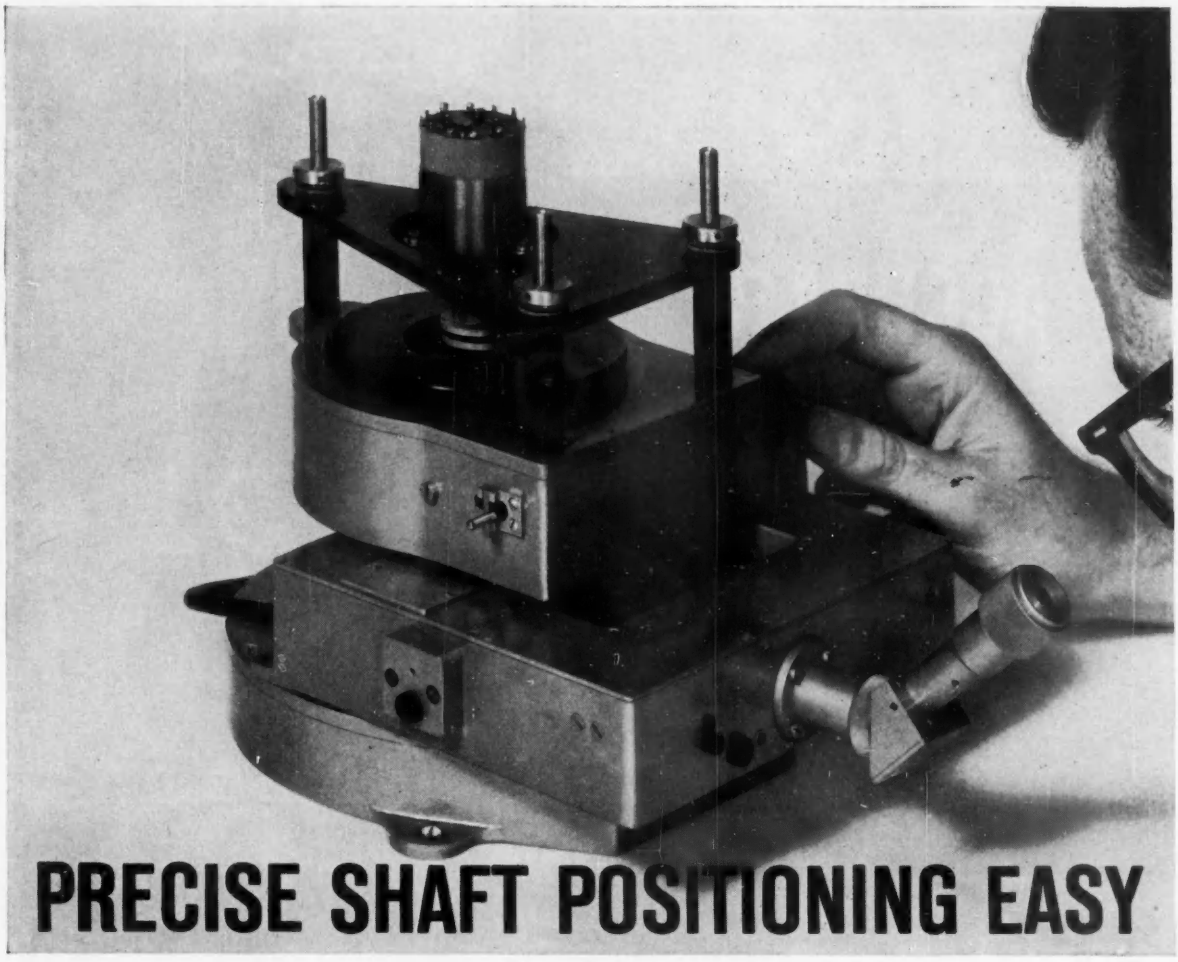
TRANSDUCERS
linear displacement • angular position • velocity • torque • force • pressure

VALVES
Differential relief, solenoid and priority valves. Flow and pressure regulators. Reservoirs and accumulators.

EXPECT MORE FROM **VINSON** SYSTEMS

Phones: TR 3-3510, ST 6-7210 • 8044 Woodley Ave., Van Nuys, California

Your inquiry will receive an immediate reply from engineers experienced in the design and application of transducers and valves for the solution of measurement and control problems.



PRECISE SHAFT POSITIONING EASY

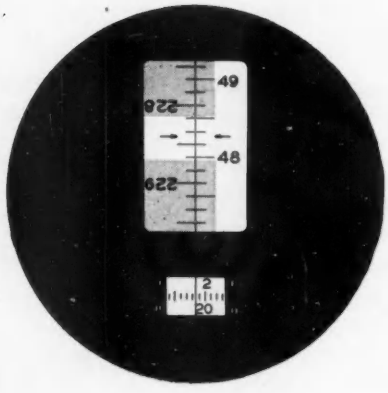
WITH GURLEY RESOLVER TEST STAND

The new Gurley Resolver Test Stand solves the long-standing need for a reliable instrument in production tests of resolvers, synchros, potentiometers and other such equipment.

The Gurley Model 7530 test stand is a precision shaft-positioning device, consisting of an optical coincidence reading system with ± 2 second accuracy, a rack and gear for precise shaft positioning, and an adaptor plate and coupling.

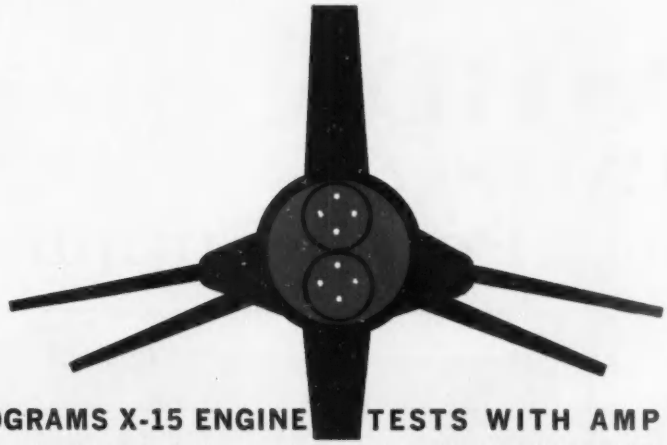
In use, the unit under test is mounted on the adaptor plate and is connected to the shaft of the test stand by a miniature flexible coupling. The shaft system is then quickly adjusted to an approximate angular position by means of the rapid drive disc. Accurate final positioning is accomplished with a slow motion drive. The angular position of the shaft is read directly to the nearest second of arc.

For an illustrated bulletin, write on your letterhead to Industrial Division, W. & L. E. Gurley, 537 Fulton Street, Troy, N. Y.



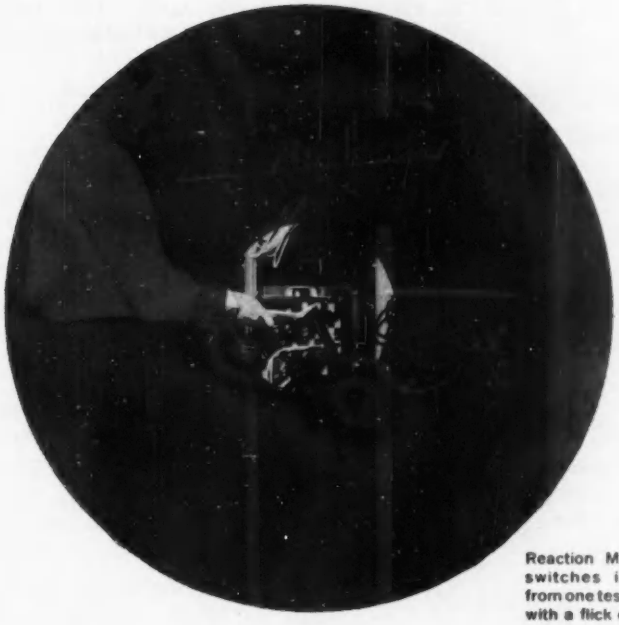
W. & L. E. GURLEY

TROY, N. Y.



Thiokol PROGRAMS X-15 ENGINE TESTS WITH AMP PATCHBOARDS

To test the 50,000 pounds of whoosh in its new X-15 engine, Reaction Motors Division of Thiokol Corporation required versatile and reliable programming systems to connect instrumentation to six different test stands. With the assistance of AMP engineers, Thiokol installed six patchboard programming systems that can connect one set of test instruments of any of six test stands with a flick of the wrist—a saving of time, personnel and equipment. In addition to tremendous flexibility, AMP systems—either universal or shielded—provide a number of exclusive features including pre-cleaning of contact pins and springs, rugged take-a-beating construction, an almost unlimited range of sizes, plus electrical characteristics suited to the most sensitive applications—all contributing to top notch reliability. **For the complete story, write for our Patchcord Programming Catalog.**



Reaction Motors' technician switches instrumentation from one test stand to another with a flick of the hand.

AMP INCORPORATED

GENERAL OFFICES: HARRISBURG, PENNSYLVANIA

AMP products and engineering assistance are available through subsidiary companies in: Australia • Canada • England • France • Holland • Italy • Japan • West Germany

LAMBDA
COM-PAK Series
Regulated Power Supplies

- Immediate delivery from stock.
- Convection cooled, no troublesome blowers.
- Rated for 24 hour continuous operation at 50°C ambient.
- Swing open back for easy access.
- Transient free-output.
- Excellent regulation.

Guaranteed 5 Years

C-280 (without meters):	0-200 VDC, 0-200 MA.	$184.50	C-880 (without meters):	0-200 VDC, 0-800 MA.	$340.00
C-281 (without meters):	125-325 VDC, 0-200 MA.	159.50	C-881 (without meters):	125-325 VDC, 0-800 MA.	315.00
C-282 (without meters):	325-525 VDC, 0-200 MA.	169.50	C-882 (without meters):	325-525 VDC, 0-800 MA.	360.00
C-480 (without meters):	0-200 VDC, 0-400 MA.	259.50	C-1580 (without meters):	0-200 VDC, 0-1500 MA.	550.00
C-481 (without meters):	125-325 VDC, 0-400 MA.	244.50	C-1581 (without meters):	125-325 VDC, 0-1500 MA.	575.00
C-482 (without meters):	325-525 VDC, 0-400 MA.	259.50	C-1582 (without meters):	325-525 VDC, 0-1500 MA.	650.00

For Com-Pak Series models with meters, add the suffix "M" to the model number and add $30 to the unmetered model price.

COM-PAK FEATURES

- Hermetically-sealed transformer—designed to MIL-T-27A
- 50 to 400 CPS input
- Semi-conductor rectifiers for higher efficiency in C-400, C-800 and C-1500 series.
- Overload protection with built-in blown-fuse indicators
- Stable, low noise wire wound reference networks and multipliers
- Oil-filled, hermetically-sealed capacitors
- Conservatively rated for continuous duty
- Easy service access without removal from rack; all tubes readily accessible for replacement
- Provision for remote DC vernier voltage adjustment
- Exclusive design, height only 5¼" (C-200 and C-400 series), 7" (C-800 series) and 8¾" (C-1500 series)

CONDENSED DATA

Regulation: *Line* Better than 0.15% or 0.3 Volt (whichever is greater). For input variations from 105-125 VAC.

Load Better than 0.25% or 0.5 Volt (whichever is greater). For load variations from 0 to full load.

Transient Response: *Line* Output voltage is constant within regulation specifications for step-function line voltage change of plus (+) 10 volts or minus (−) 10 volts rms within the limits of 105-125 VAC.

Load Output voltage is constant within regulation specifications for step-function load change from 0 to full load or full load to 0.

Ripple and Noise: Less than 3 millivolts rms.

AC Output: (unregulated) . . . 6.5 VAC (at 115 VAC Input). C-200 Series . . . 10 AMP; C-400 Series . . . 15 AMP; C-800 Series . . . 20 AMP; C-1500 Series . . . 30 AMP.

AC Input: 105-125 VAC, 50-400 CPS

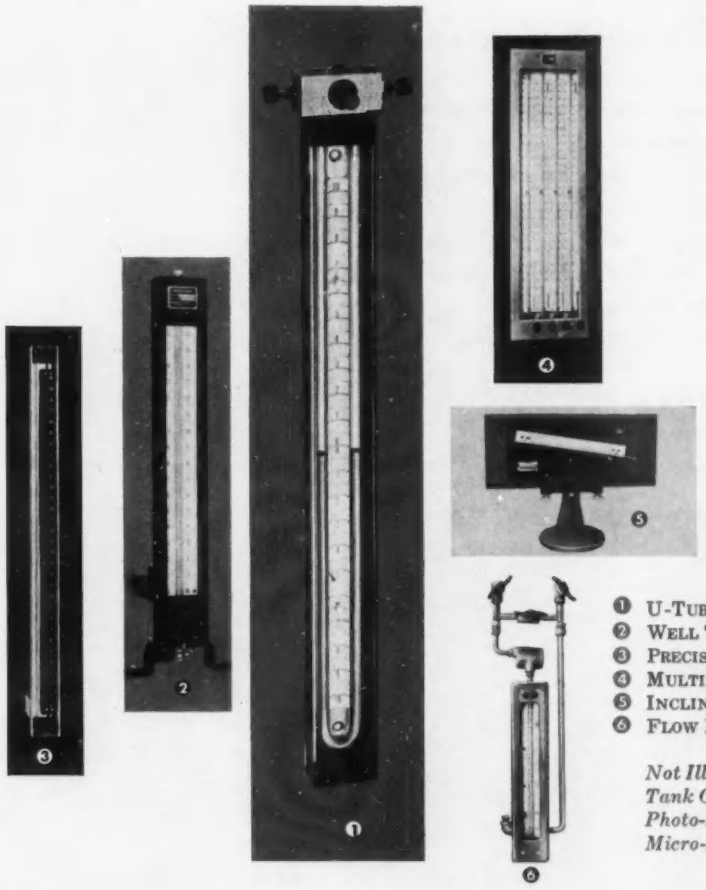
Controls: DC Output Controls: Band-switches and screw-driver adjusting vernier-control, rear of chassis.

LA 111

SEND TODAY FOR COMPLETE DATA

LAMBDA ELECTRONICS CORP.

11-11 131 STREET • DEPT. 4 • COLLEGE POINT 56, N. Y. • INDEPENDENCE 1-8500



❶ U-Tube
❷ Well Type
❸ Precision Well Type
❹ Multiple Tube
❺ Inclined
❻ Flow Meter

Not Illustrated:
Tank Gauges
Photo-Manometer Panels
Micro-Manometers

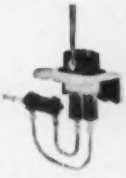
Announcing a complete line of Manometers as Trimount Instruments joins General Controls

Through the acquisition of the Trimount Instrument Company, General Controls now offers a complete line of modern, accurate manometric instruments for every application. This famous product line will continue to be produced to the same high engineering standards that have brought broad acceptance to both Trimount and General Controls in the industrial instrumentation field. And all products manufactured and distributed by the Trimount Instrument Division will be sold and serviced through General Controls' international network of factory branch offices. Also included in the Trimount line are the "Crown" Hydraulic Remote Control Systems and the Electronic Level Indicators/Controllers.

General Controls maintains 44 factory branch offices throughout the United States, Canada and Western Europe. For complete information on any Trimount product, check the yellow pages for your local factory branch or Trimount representative.

Electronic Level Indicators/Controllers
Line includes capacitance type ON-OFF Controllers. Also transistorized linear and proportioning Level Indicators/Controllers, designed for use with liquids, gases and solids – including cryogenic materials.

Hydraulic Remote Control Systems
Self-contained hydraulic systems for positive, infinite positioning of remotely located levers, guides, valves or actuators.



Manufacturers of Manometers, Electronic Level Indicators/ Controllers and Hydraulic Remote Control Systems

TRIMOUNT INSTRUMENT DIVISION

GENERAL CONTROLS CO. 8080 McCormick Boulevard, Skokie, Illinois

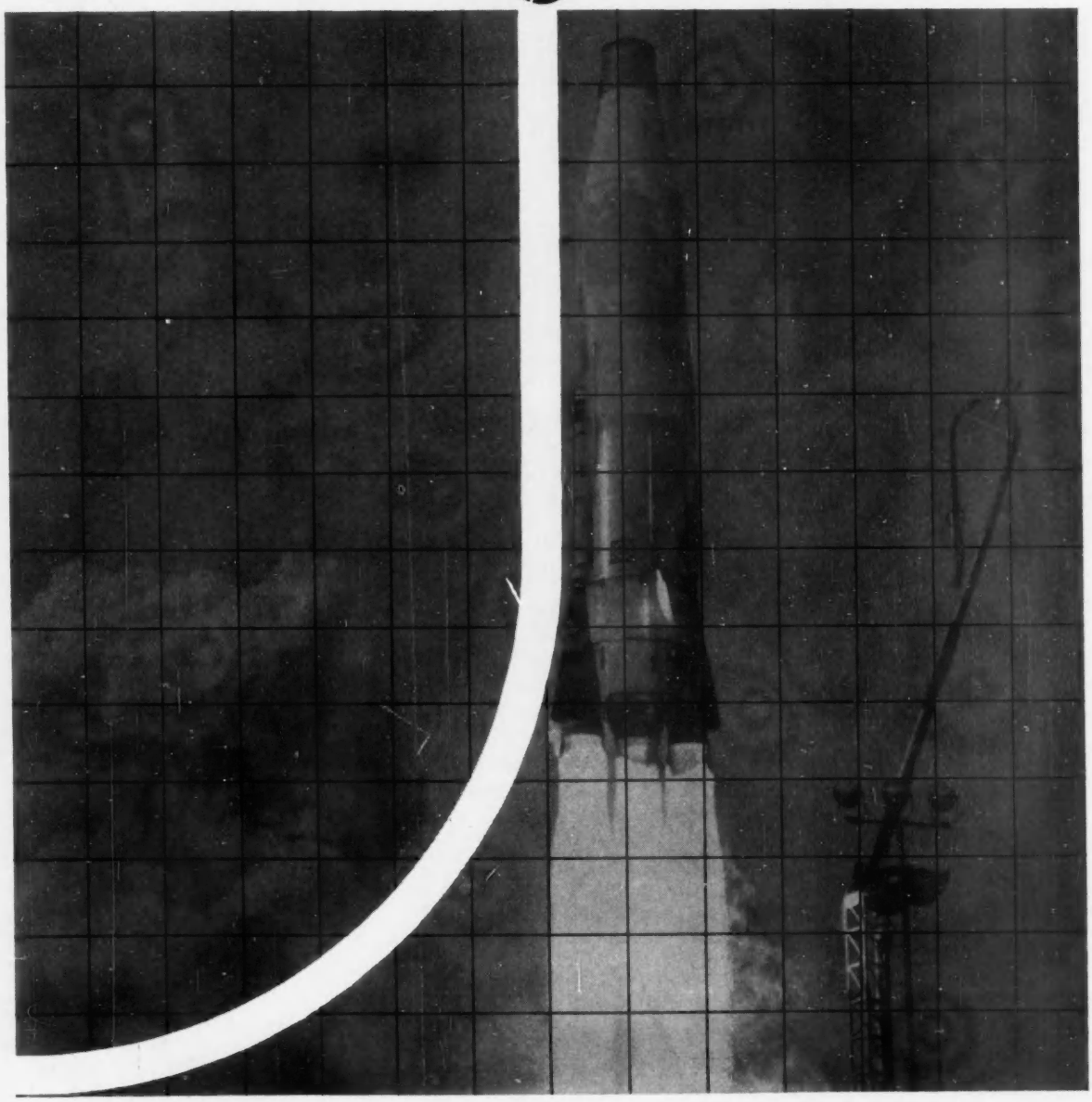
The first six years of **S**pace **T**echnology **L**eadership

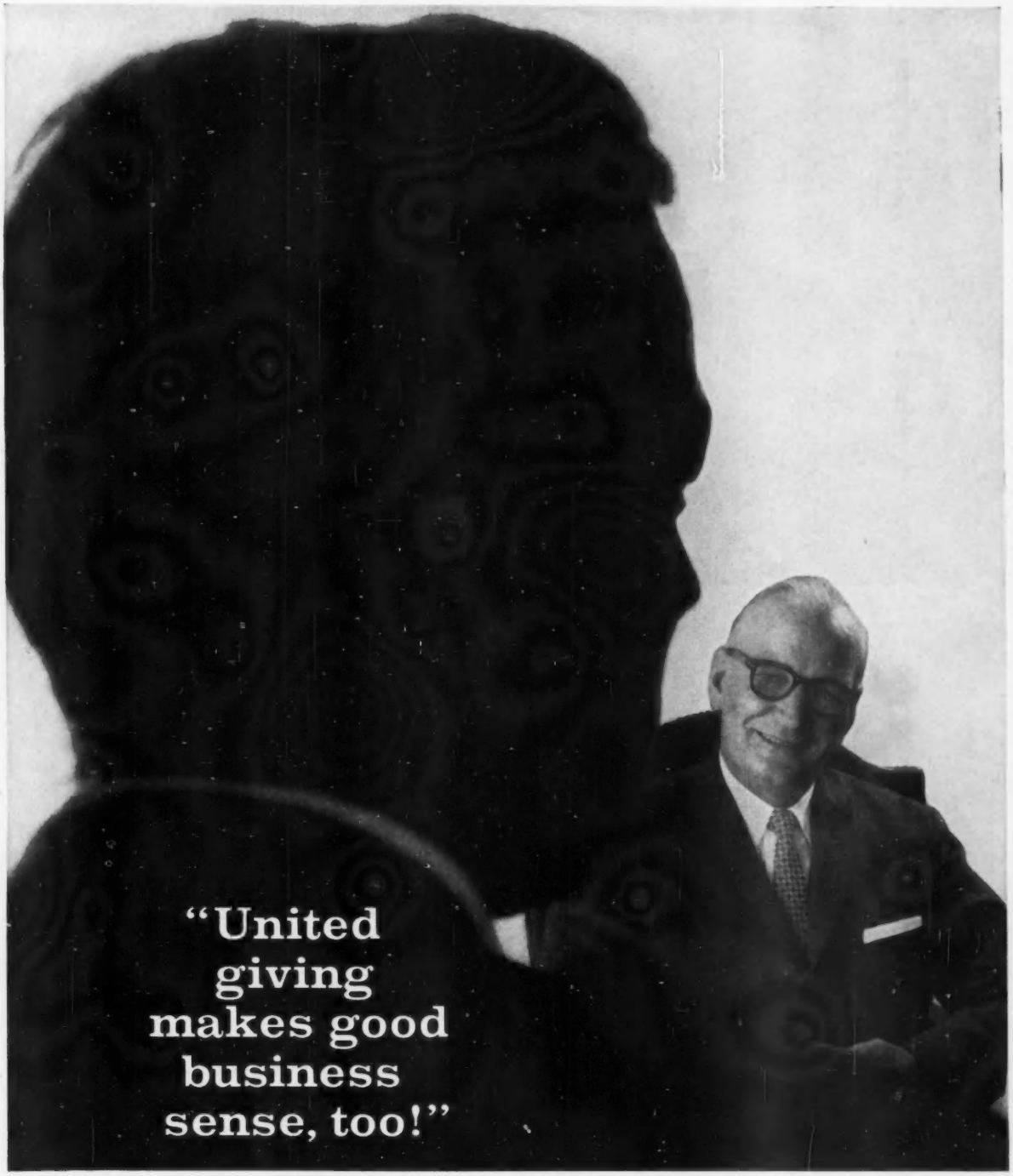
Since 1954, when the Air Force ballistic missile program was accorded top national priority, Space Technology Laboratories has been engaged in virtually every major phase of research, development, testing and technical management of missile and space systems • STL's contributions have hastened the day of operational capability for Air Force ballistic missiles, and have been applied as well in satellite projects and space probes • Today, as STL's activities expand in significance and scope, STL offers exceptional opportunity to the outstanding scientist and engineer whose talents and training will add to, and benefit from, the accumulated experience that has enabled STL to conceive and accomplish major advances in the state-of-the-art • STL's creative flexibility, anticipating and responding to the demands of space progress, ranges in application from abstract analysis to complex hardware fabrication for military and civilian space projects • STL invites scientists and engineers to consider career opportunities in the atmosphere of Space Technology Leadership. Resume and inquiries will receive meticulous attention.

SPACE TECHNOLOGY LABORATORIES, INC. P.O. BOX 95005Z, LOS ANGELES 45, CALIFORNIA

a subsidiary of Thompson Ramo Wooldridge Inc.

Los Angeles • Santa Maria • Edwards Rocket Base • Cheyenne STL Cape Canaveral • Manchester, England • Singapore • Hawaii





Every business has a vital stake in the welfare of its community. The businesslike way to protect these interests is to support your community The United Way. Your United Fund or Community Chest Campaign takes care of many community needs without the confusion and waste of separate appeals.

Your company can contribute in *three* important ways! ■ Make sure your company makes a generous corporate contribution. It helps protect the welfare of your employees and customers. ■ Help your employees meet their obligations through easy payroll payments. Experience shows this often doubles, even triples, results. ■ Stimulate executive participation in support of your local fund. Such participation helps safeguard the dollar investment made by your company and its employees.

Remember, giving The United Way helps your community *and* your company. **GIVE THE UNITED WAY**

ENGINEER'S BIRD GUIDE

Litton has designed and developed an airborne computer that can perform 250,000 additions per second in a complete package less than 7 cubic feet in volume. This *general-purpose* data processor incorporates an advanced combination core and drum memory, high-speed switching circuits, and esoteric logic organization that features dual instruction registers and interlaced operand and instruction access cycles.

Litton airborne systems currently in production for manned aircraft are for the Grumman A2F, W2F, WF2, and the Lockheed F-104 and P3V.

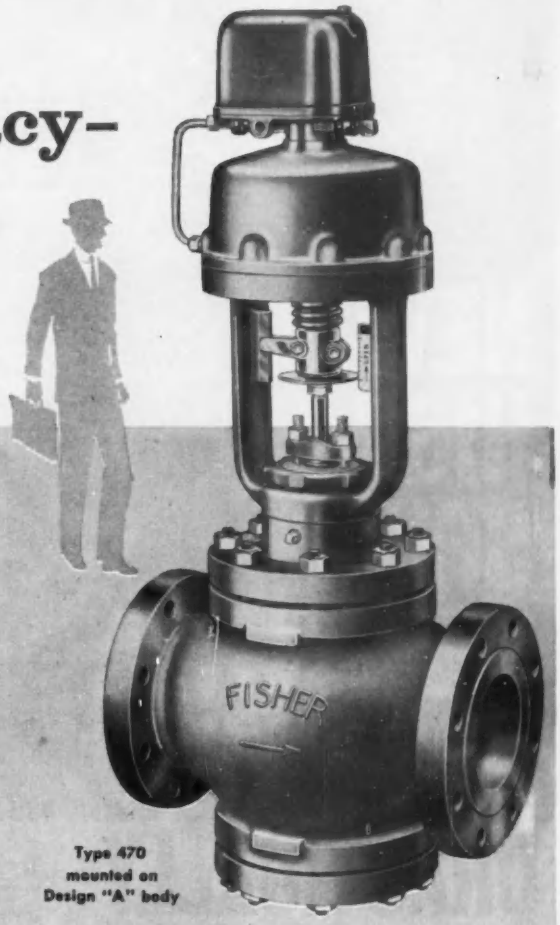
Engineers experienced in logic design, circuit design, computer programming and disciplines related to computer systems, guidance and control systems, and tactical data systems will find positions of absorbing interest in our R&D and manufacturing facilities in Los Angeles suburbs. A laboratory for research and development in advanced communications is maintained in Waltham, Massachusetts. If you can make significant contributions in any of these areas, write to Mr. Don Colvin, Research and Engineering Staff, Ventura Freeway at Canoga Ave., Woodland Hills, Calif.

LITTON SYSTEMS, INC.
Computer Systems Laboratory

YOUR **FISHER/MAN** STANDS BEHIND THIS PNEUMATICALLY OPERATED PISTON...

FOR Inherent Accuracy–Power–Speed and Stability

FISHER TYPE 470 P.O.P.



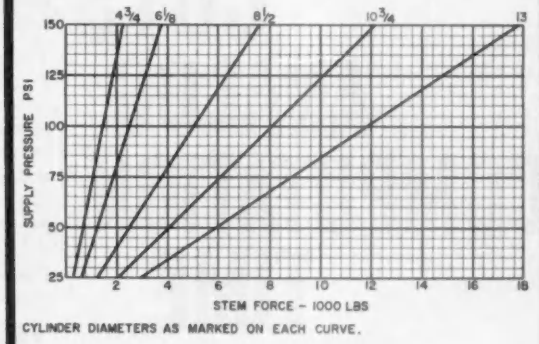
Type 470 mounted on Design "A" body

- **Delivers same power in either direction at any point of the stroke.**
- **Adaptable to virtually all types of valve bodies including Butterfly valves.**
- **No air set required—utilizes clean, non-corrosive air or gas up to 150 psi.**
- **Easily reversible actuator can be changed in the field.**

This small, compact piston actuator incorporates its own positioner mounted integrally on top of the cylinder. Positioner receives any of the normally used pneumatic instrument signals. Then, without an air set, actuator utilizes the full potential of the available instrument or gas supply to provide exceptional speed and power. Series 470 is available in six basic sizes and can be supplied for travel up to 4". Basic actuator can also be furnished with a handjack, hydraulic snubber, pneumatic safety devices or as a spring return unit. Write for Bulletin E-470.

PERFORMANCE DATA

Air Consumption (Static)	20 SCFH at 100 psi supply.
Instrument Signals	3 to 15 psi, 5 to 25 psi, 6 to 30 psi, 12 to 60 psi. Suitable for split range also.
Temperature Limitation	175°F.
Maximum Hysteresis	0.15% of total stroke or instrument signal.
Repeatability	0.03% of the total stroke or instrument signal.
Resolution Sensitivity	Minimum change in the measured variable to produce an effective movement of the final control element is .02% of the instrument pressure range.
Frequency Response	1.4 cps for the Size 60. 4 cps for the Size 30.
Load Sensitivity	Percent of total travel per 100 lbs. stem force is .065% for Size 60.



CYLINDER DIAMETERS AS MARKED ON EACH CURVE.

AVAILABLE STEM FORCE

IF IT FLOWS THROUGH PIPE ANYWHERE IN THE WORLD...CHANCES ARE IT'S CONTROLLED BY...

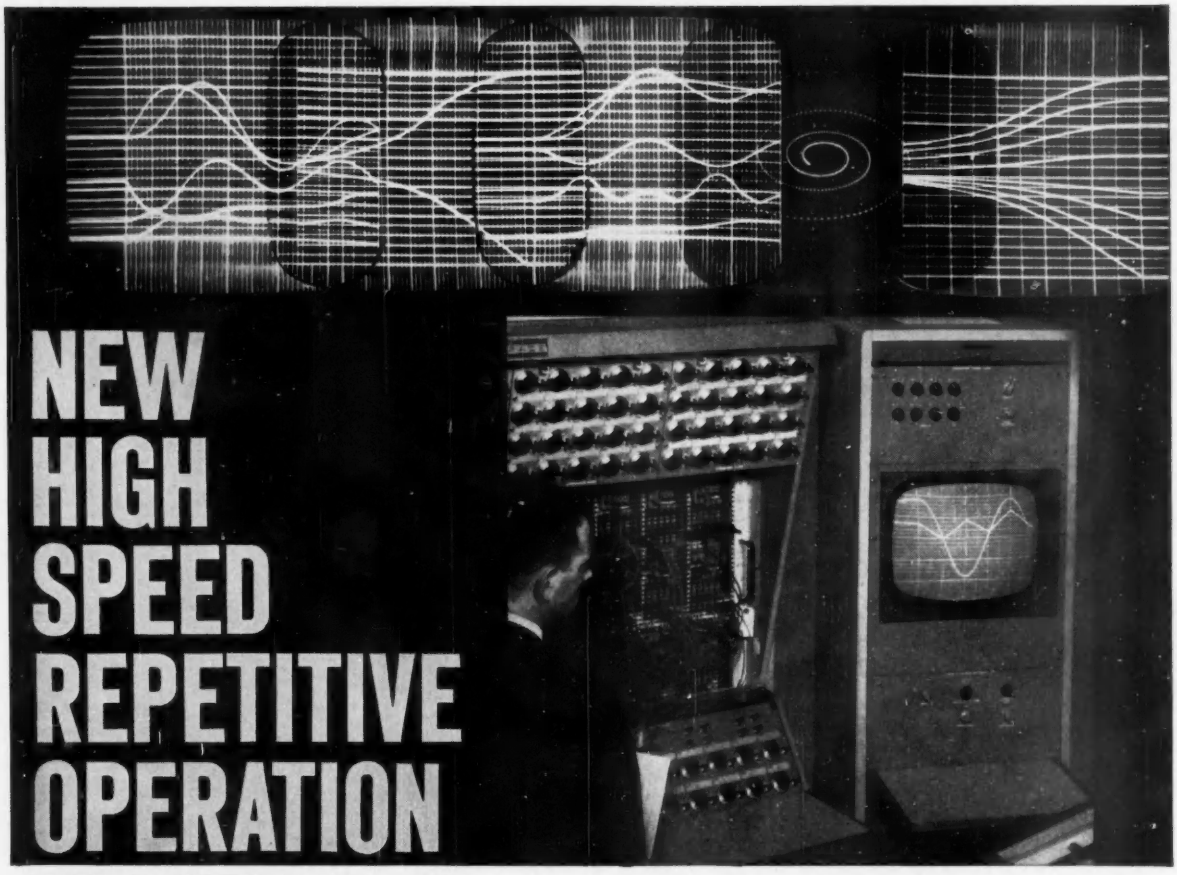
FISHER GOVERNOR COMPANY

Marshalltown, Iowa / Woodstock, Ontario / London, England

BUTTERFLY VALVE DIVISION: CONTINENTAL EQUIPMENT COMPANY, CORAOPOLIS, PA.

FISHER® Controls

SINCE 1880



NEW HIGH SPEED REPETITIVE OPERATION DRASTICALLY CUTS ANALOG COMPUTATION TIME

The new EAI high speed repetitive operation system is ideally suited to systems design work because it produces solution repetition rates of 10 to 50 per second with *no loss of real time accuracy.* Used with Electronic Associates, Inc. Model 231R analog computer, it provides instantaneous change from real time operation to high speed repetitive operation by a single control . . . requires no re-patching . . . allows real time recording of selected solutions.

This newly developed system for PACE® analog computers can be used as a highly accurate and extremely versatile method for solving a variety of computational problems with greater speed and precision. It is an especially useful engineering tool for design problems involving simulation of servomechanisms, optimization of systems, solution of boundary value problems and mathematical 'model building'. High speed repetitive rates insure rapid approximation of optimum system parameters for control systems and determination of stability regions.

Outstanding features of the EAI high speed repetitive operation system include—

- **solution repetition rates of 10 to 50 solutions per second**
- **precision crystal oscillator control of display unit timing**
- **computer repetitive rate remotely slaved to precision crystal oscillator**
- **switched control of compute time with continuous control between steps**
- **electronically generated display grid . . . constant for repetitive rates**
- **simultaneous display of up to eight variables**

For complete details write for Bulletin AC-6034 describing the new EAI high speed repetitive operation system.

EAI ELECTRONIC ASSOCIATES, INC. *Long Branch, New Jersey*

The Missing Market in Computing-Control

After what looked like a highly satisfactory start, sales of "general purpose" digital computers for process control applications have failed to live up to optimistic expectations. Although the steel and utility industries (particularly electric generating plants) are now adding computers for control at a relatively rapid rate, the petroleum and chemical processing industry has adopted a far more cautious attitude and seems to be demanding better evidence of economic justification.

Missing link

Interviews with potential users of such equipment have turned up an interesting opinion: many of these men believe there is a key gap in the chain of commercially available equipment for computing-control. The missing link: *special purpose computers* to control a specific part of a process.

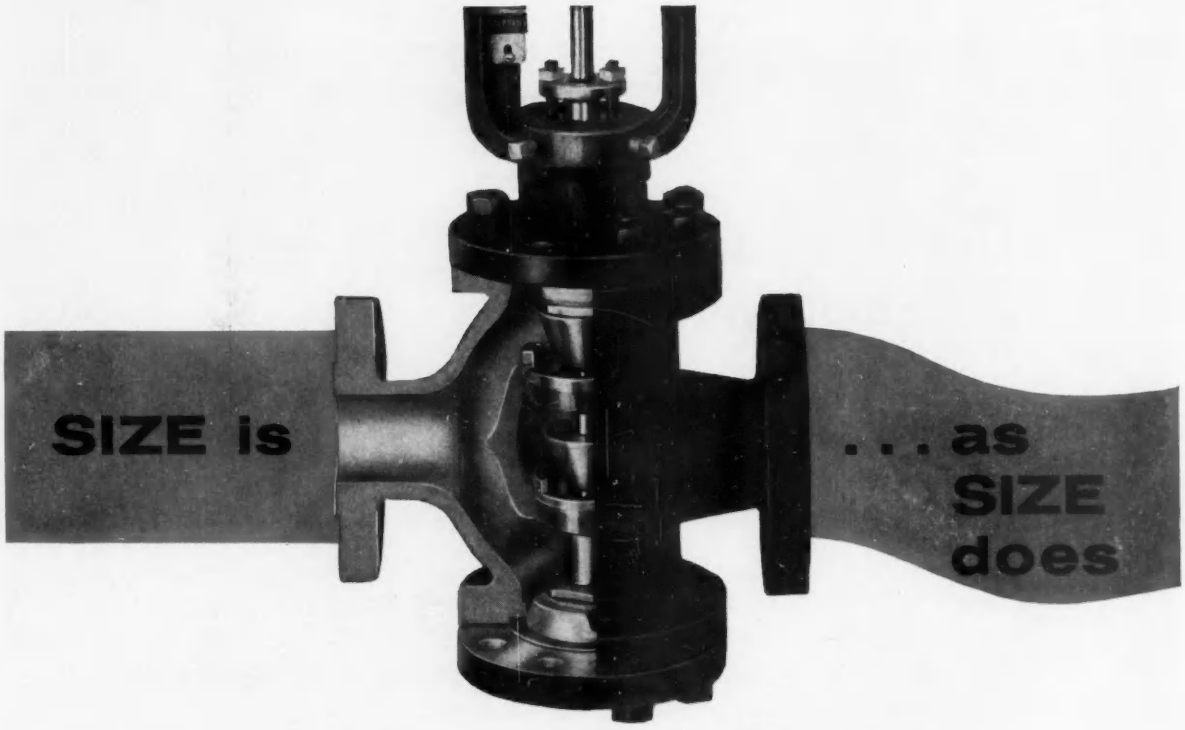
By special purpose, these control engineers mean a stored program computer (either digital or analog), whose program is wired in, cannot be easily changed. This contrasts to general purpose process control equipment, like the RW-300, Libratrol 1000, RCA 110, etc., whose program is inserted by some medium like punched tape and can be changed at will. Although there are almost 20 different general purpose digital computers being offered for process control, there are only two special purpose digital machines commercially available: Daystrom's Flowcon, designed to control the Universal Oil Products Molex process, and Westinghouse's Opcon.

Dollars and cents

What makes the special purpose concept look so attractive is strictly a matter of dollars and cents. Flowcon, for example, costs about $20,000, including computer and instrumentation, a cost easier to justify than price tags ranging from $125,000 to $300,000 for a general purpose computer installation. Phillips Petroleum Corp.'s T. J. Wherry points out "historically lower cost installations seem to show higher percentage returns."

To date the expense of a general purpose installation for control has been increased by the necessity for a special engineering study of the process for computer control. Then most of the machines have to be modified to fit the particular process in hand. Daystrom, for example, claims it has yet to build two of its general purpose "information systems" that are exactly alike. TRW Computers Co. and General Electric agree.

The special purpose computer approach is not automatically less expensive than a general purpose approach. For example, Information systems, Inc. has tried to sell its DDA-type com-



C_v is the thing to see

Take a hard look at fundamentals when you buy diaphragm control valves.

Valves of the same size won't necessarily deliver the same *amount* of valve performance. Flow capacity, not nominal size, is the dollar dimension to look at.

K&M valves provide the largest flow coefficient available. That means, in some cases, you can use the next smaller size at a worthwhile saving in dollars. In all cases, K&M's higher C_V produces a smaller pressure loss in the body; it places the flow restriction where it belongs . . . at the controlled inner valve.

Averaging 140% of cross-sectional pipe area K&M valves provide more space for fluids to flow . . . smoothly, freely with less turbulence.

Result—you get what you are really after . . . better controllability at lower cost.

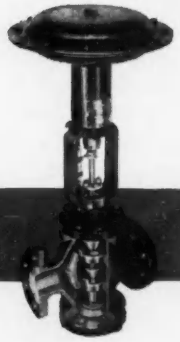
Why not size up your control valve buying decisions on a real—not nominal—size basis?

Request Bulletin CV53

C_V COMPARISON TABLE

Valve Size	K&M	Valve B	Valve C
¾"	10.9	8.4	8
1"	17.3	14.9	12
1½"	39.1	33.2	28
2"	61	57	48
2½"	97.7	71.0	72
3"	150	116	100
4"	219	197	165
6"	500	364	360

Based on the maximum Cv at rated travel through the valve body. From manufacturers' most recent slide rules or tables.



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puter (designed by Genesys Corp. which was merged along with Panellit into ISI) as a special purpose machine but found that the modifications required ran the cost higher than the general purpose 609 computer which ISI also sells for process control.

Special black box

Here is the approach that looks most promising now. A process or a unit operation that is widely used—such as furnace control or flame monitoring and control—would be studied and a special purpose digital computer designed for that particular application. Because it is specially tailored, there is a minimum of extra components; and because it can be built in volume, upwards of 100 units, the special purpose computer black box could sell at an attractive price—perhaps $20,000 to $30,000.

This is the philosophy behind the Flowcon computing-control which UOP is currently selling on its Molex process. Daystrom has plans to bring out other special purpose computers for control jobs in the utility, steel, chemical products, and oil refining industries. Some of these will be developed in collaboration with UOP, but others will be developed by Daystrom alone. At least one other computer manufacturer will offer a special purpose digital device to control a specific unit operation within the next 12 months.

Analog opening

For the most part, however, digital computer makers are neglecting this missing link, thus leaving a big opening for analog equipment makers. A segment of process control engineers prefer analog equipment for control applications anyhow. And manufacturers are taking advantage of this. Minneapolis-Honeywell, for example, offers a fractionator reflux analog computer (developed by Phillips Petroleum Co.) and a gas flow computer system. Electronic Associates, a maker of analog equipment for simulation and engineering problem solving, has been working on a process control computer, may announce it early next year.

At least one executive in the computer industry feels that special purpose computing-control devices will be the dominant factor in the market by 1963. Because of this innovation he and others in the field now put the potential market for all computing-control systems at $500 million per year by 1970. But to reach that figure, makers are counting on filling the missing link in computing-control equipment with special purpose devices that can be sold in large volume.

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CIRCLE 98 ON READER SERVICE CARD

TRANSISTOR CENTER U.S.A.

Control
ENGINEERING

NOVEMBER 1960

Needs to Know

"Start me with the basic physical principles. On them build an argument and take me on through the derivation of application formulas. I'll take it from there. Don't give me a cold start from 'cook-book' formulas and tell me how and to what I should apply them. I'll figure that out." So writes an engineer who contends that too many schools and publications are presenting cut and dried techniques for the user to take on faith without giving him the conviction that springs from an understanding of how the techniques were derived.

Another engineer writes, however, that he doesn't have the time or the need to fully understand the basic derivations of all control techniques. He wants us to put in perspective new methods of control systems analysis and design. He needs to know what the available methods are, the most powerful equations distilled from the method, to what sorts of systems problems they apply, and what application limitations the equations face. A publication that does this, he says, gives him enough knowledge to be selective. He can then decide which of the new techniques he should learn in detail.

We've heard that it's impossible to serve more than one master. Regardless of rusty cliches, we believe that technical publishing is effective only when it meets reader needs. Both of our correspondents have a need to know. We aim to fill both needs at the same time. Our method is to present new techniques in the perspective needed by the second correspondent and to also offer complete derivations for the first correspondent. The derivations are either in the body of the articles we publish or are available on written request. Judge our method by examples: "Don't Overlook Positive Feedback," pages 115-119 in this issue, is one. The author places the proposition in perspective and fully derives application equations for a common problem. Later in the article he gets to the application equations for a more special problem. We then offer to mail his derivation to any reader who writes us for it.

The control field will adopt more and more complex mathematical techniques. Control engineers will apply them to multivariable problems embracing larger and larger arrays of interrelated factors. We believe that our double-barreled editorial approach described here will prepare control engineers to do the work.

W. E. Vannah

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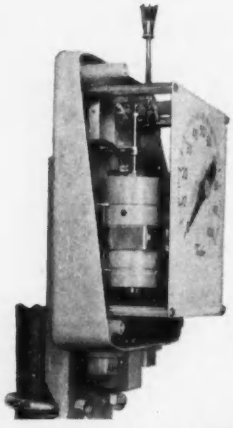
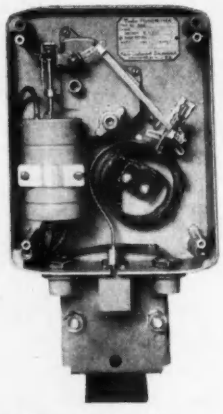
A high-accuracy, low-cost, motion-balance transmitter for Gage Pressure, Volumetric Pressure, Volumetric Load, Temperature



Diagonally-split case permits calibration adjustments to be made without removing dial.



Single-package pneumatics . . . servo-powered follow-up and relay valve, encapsulated movement and actuating element are easily removable, replaceable.

Taylor's new integrated line of pneumatic transmitters features servo-driven indication as an option on the indicating model. This provides ample power for process alarms—and other auxiliary functions such as digital encoders and potentiometers—with no loss of accuracy in the transmitted signal. Not only does it satisfy today's requirements . . . it provides for possible future needs. Other important features of the TRANSCOPE **210T** include:

- **High accuracy.** Transmitted signal is within ½% of the input signal. Indication is within ±1% of actual value.
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- **Threshold sensitivity.** 0.1% of input span. Low-friction drive mechanism permits accurate handling of low-energy input signals.
- **Designed for easy maintenance.** Only 3 basic parts. A high quality encapsulated motion amplifier; single-packaged pneumatics . . . servo-powered follow-up and relay valve; interchangeable, time-tested actuating elements.
- **Lower inventories.** Benefits large users of instruments by utilizing actuating elements which are common with FULSCOPE® and other Taylor indicating, recording and controlling instruments.
- **Conveniently calibrated.** Diagonally-split case makes all adjustments easily accessible by merely removing cover.
- **Weatherproof case.** Special baked epoxy resin finish on die-cast aluminum case . . . designed for field installation.
- **Adaptable mounting.** Universal bracket permits wall or pipe installation.
- **Non-indicating model (211T)** has same performance as 210T except for process indication.

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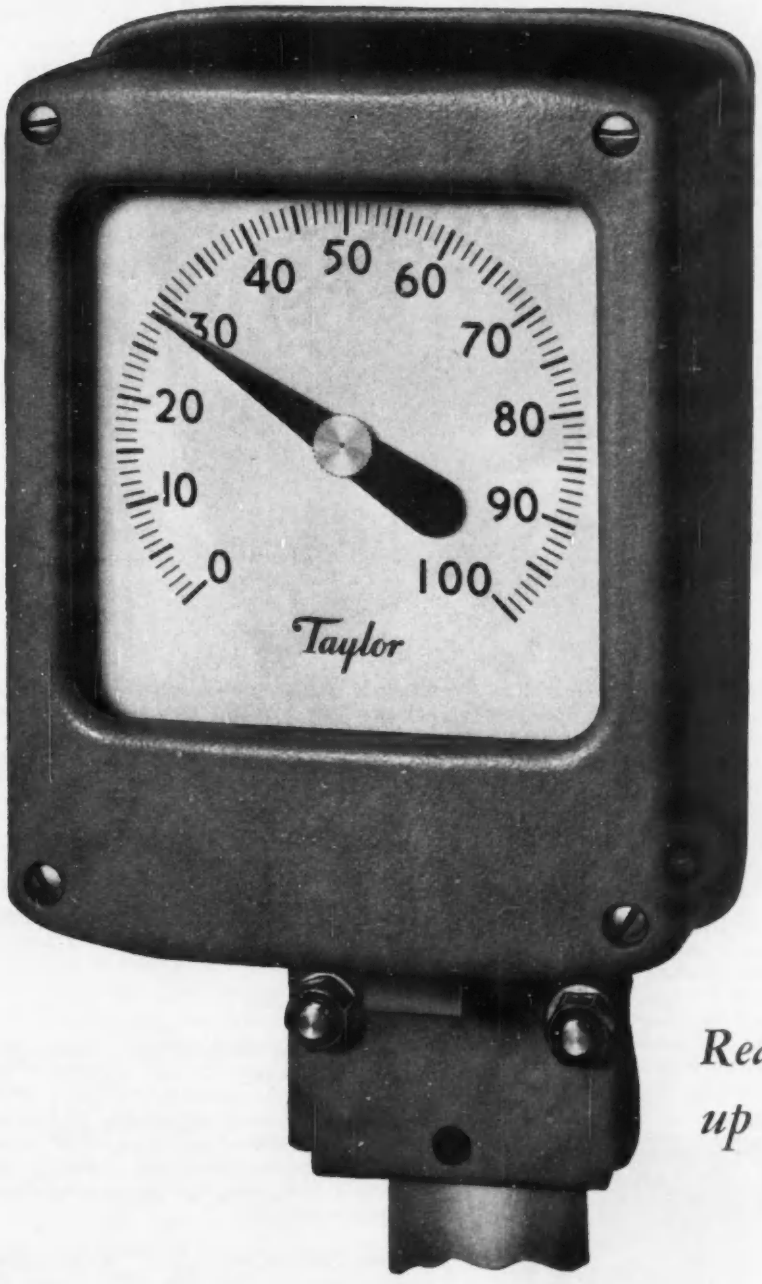

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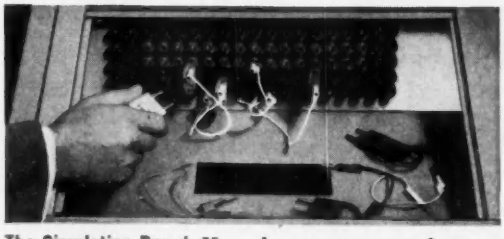
Did you ever use a computer as versatile as the DONNER 3100?

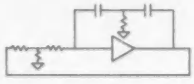
The Donner 3100 isn't for people who merely wish to push buttons. It is a medium sized, high accuracy computer, simple to operate, but designed so it doesn't horsecollar the operator. In its class (20 to 100 amplifiers) it is the most versatile analog computer. Two big reasons for this are the 3100's *uncommitted amplifiers* and its *simulation board*, an auxiliary patchbay electrically connected to the main removable problem board. Here's what they do:

Uncommitted Amplifiers. The 3100's amplifiers are not already wired as summers or integrators. The operator patches his resistors and capacitors to the amplifier. Obviously, he is not limited to using computing components with fixed values. If he wants to use only two components per amplifier, all the rest are free. Depending upon your needs, the 3100 can be supplied with up to 50 amplifiers per console and two or more consoles may be slaved.



The Simulation Board. Here the operator can plug in a wide variety of components—resistors, capacitors, pots and diodes. He can synthesize (a) complex input and feedback networks for amplifiers, (b) complex resistor-diode limiting circuits and (c) resistor-capacitor-inductor filter networks. Programming these circuits on the simulation board is far simpler and saves amplifiers. For example, a mass-spring system is oscillatory and usually needs three amplifiers to simulate it:

But this clever little circuit does the same thing:



You see, we have eliminated two amplifiers by using the simulation board.

Speaking of economy, **$13,995** buys a Donner 3100 with 30 stabilized amplifiers and 55 potentiometers. A full line of nonlinear and accessory equipment is available. Free instruction on computer theory and operation is included.

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29

Closed-Loop Computer Control at LULING

Monsanto's ammonia unit at the Barton Plant is now under complete full-time control of an RW-300 digital computing-control system and has been operating successfully for several months. During this short period the installation—the the single largest and most complex computer controlled chemical process operating today—has already given good indications of meeting the economic payout goal set for it.

In this comprehensive 12-page article the authors reveal step-by-step the factors leading to Monsanto's successful computing-control system. As examples they describe how the system was economically justified; how ammonia is made; how the project team used plant data to develop the mathematical model; what setpoints and other factors the computer calculates; and, finally, how the team revised plant instrumentation, installed the computer, tested the computer programs, and put the computer on line for closed-loop control.

R. D. EISENHARDT
T. J. WILLIAMS
Monsanto Chemical Co.

Three years ago Monsanto Chemical Co. joined with Thompson-Ramo-Wooldridge Products Co. in establishing a feasibility study team to determine whether or not digital computer control would be possible for Monsanto's ammonia unit at Luling, La., and to estimate the economic and technical benefits from such a control system. The mathematical model resulting from the study indicated the manner by which various process improvements could be made and provided a basis for estimating the economic justification of a control computer. Engineering evaluation indicated that the proposed computing-control system offered a potential economic payout.

Once the decision was made to go ahead, Monsanto ordered an RW-300 digital computer from TRWP, and the two companies established a second team—offering a wide range of needed specialties—to assume control of the project. What these two teams accomplished is told here.

Justifying the computer control system

While the installation of a process computer control system might very well be justified as a research or development project, Monsanto chose to justify the computer system for the ammonia plant, Figure 1, by its achieving specified economic and technical objectives as part of a producing unit. The objectives are listed in Table I.

Briefly, these are the steps in the engineering evaluation. Such uncontrolled variables as atmospheric conditions—mainly temperature—affect the capacity of the producing equipment. Basically the computer's task is to minimize the effect of uncontrolled variables.

It is known that such things as a line of thunderstorms passing across a plant during hot days enables production to be increased because of the cooling effect associated with and immediately following the storms. It is also known that the plant's production capacity is greater during the winter months than the summer months. With this in mind, data was collected to obtain a relationship between daily production and effects of atmospheric changes. Plots of such data, broad arrays of points scattered about a line, did in fact indicate increased production as temperature decreased.

The next step was to obtain a function expressing the average production under operator control of the plant. To do this, a regression analysis of the production data was performed on an IBM 704 computer. The resulting function was plotted along with available temperature data. Next, the function was shifted

up to pass through the maximum points of the production data. This new plot served as a measure of the maximum increase in production that could be expected, assuming that the maximum points of the data were correct. Since some raw data had to be adjusted due to equipment configurations, a conservative estimate of two-thirds of the indicated production increase was established as the basis for economic justification of the computer control system. Having set this ground rule, the possible increase in production based on daily average temperature was calculated. (The difference between the average production curve and the indicated maximum production curve was greater for the summer months than for the winter months.) In this way the feasibility study showed what could be added to the credit side of the project.

On the debit side, however, were the costs of installed equipment, procurement and training of personnel to maintain the system, design, engineering, installation, and overhead. Final analysis revealed credits sufficiently exceeded debits to meet Monsanto's requirements for return on investment.

How ammonia is made

The ammonia unit at Luling, built in 1954 by the Chemical Construction Corp., is operated by Monsanto's Inorganic Chemicals Div. The plant itself is shown in Figure 1. As the photograph and the overall process and equipment diagrams—Figures 2 through 6 in the spread on pages 106-107—indicate, the ammonia plant is a widespread, complex operating unit.

The chemical equation for ammonia is:

$$3H_2 + N_2 \leftrightarrows 2NH_3$$

In the primary reformer a mixture of steam and natural gas (principally methane) reacts in the presence of a catalyst to produce hydrogen (for the ammonia) and carbon monoxide. External heat is supplied to this unit from a reformer furnace burning natural gas. Heat exchangers preheat the primary reformer feed gas and achieve a utilities savings. Natural gas thus serves both as a feed and a fuel for the ammonia process. Figure 3 shows some of the process equipment and conventional control instrumentation concerned with the primary reforming area. Reformer temperature is maintained by a furnace combustion control system, Figure 4. Here, the temperature measurement from the reformer cascades into the fuel gas flow control loop. The fuel gas flow measurement also feeds indirectly into other portions of the combustion control arrangement.

The secondary reformer burns some of the hydrogen from the primary reformer with air to supply heat for further catalytic conversion of methane and steam and to remove nearly all oxygen from the air. This step provides the nitrogen for the ammonia. Here the addition of flue gas allows independent regulation of the H_2 to N_2 ratio and the secondary reformer temperature, permitting maintenance of the methane content in the output at a sufficiently small value for efficient operation.

The CO converter, or shift converter, Figure 5, uses a catalyst to accomplish the water-gas-shift reaction which reacts most of the remaining carbon monoxide with additional steam to produce hydrogen and carbon dioxide. The proper amount of steam must be added to convert the CO to CO_2, shifting the H_2 to N_2 ratio from about 2.7 to 1 at the secondary reformers exit to about 3.1 to 1 at the converter exit.

The low pressure purification system employs an absorbing agent such as mono-ethanolamine (MEA) to remove as much CO_2 as possible from the synthesis gas stream as the first step in its purification.

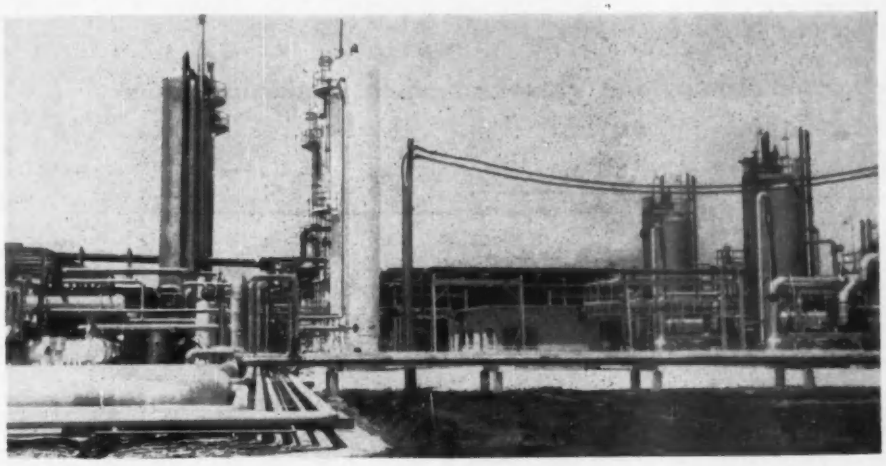
The compressors, Figure 6, increase the production capabilities of the plant. The chemical reaction producing ammonia involves an equilibrium between nitrogen and hydrogen raw materials and the ammonia product. This equilibrium is displaced toward the production of more ammonia by higher pressures and by lower temperatures. However, low temperature reduces the rate of reaction, thereby requiring a larger reactor to achieve the same ammonia production rate. The synthesis reactor and the compressor systems must therefore be designed together to get the most economical combination of compressor pressure and reactor size to obtain the required production rate. A five-stage compressor plant is usual to achieve the 5,000-psi pressure needed by the synthesis units.

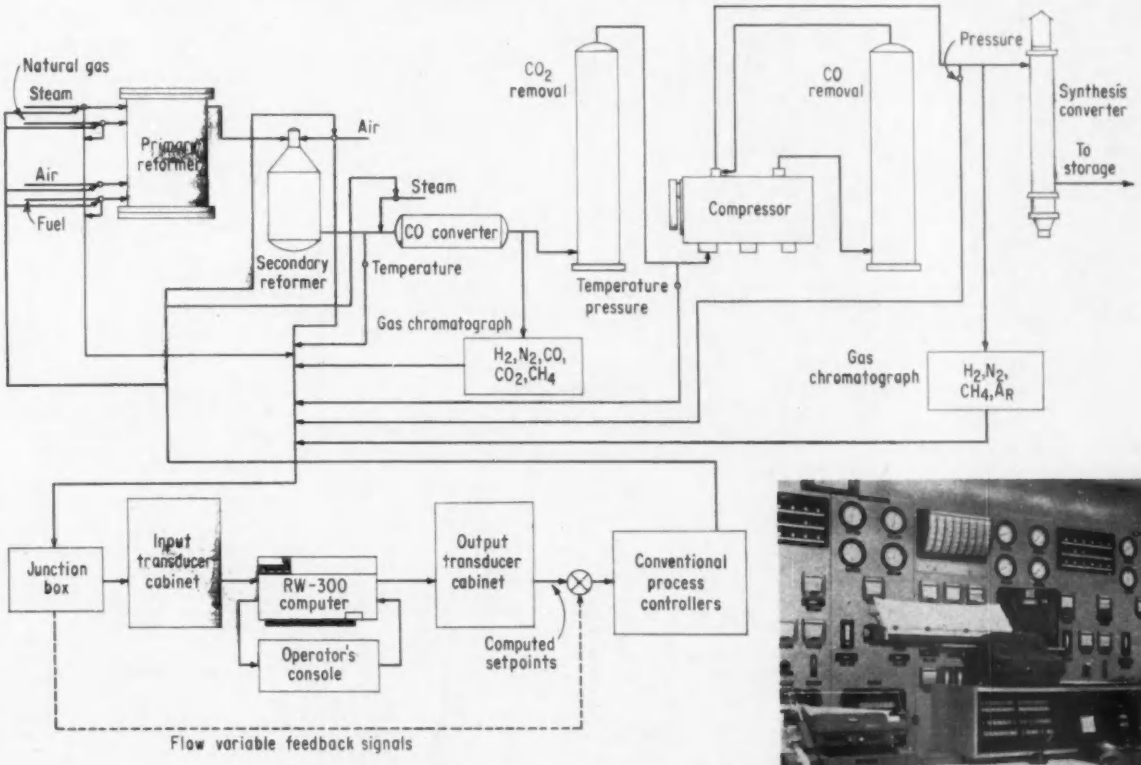
The high pressure purification system prevents destruction of the synthesis catalyst by removing the last traces of CO and CO_2 from the synthesis gas. A

TABLE I
CRITERIA FOR JUSTIFYING MONSANTO'S COMPUTER CONTROL SYSTEM

1. Maintain maximum gas flow in spite of changing weather and process conditions.
2. Maintain an optimum hydrogen-to-nitrogen ratio.
3. Maintain an optimum methane concentration at the shift converter exit unless in conflict with 1 or 2.
4. Maintain maximum shift efficiency if not in conflict with objectives 1, 2, or 3.
5. Maintain objectives 2, 3, and 4 under reduced flow conditions.
6. Reduce raw materials flows immediately and safely to compensate for any loss of compression.
7. Log out all important process variables.
8. Provide the plant operator with messages in case of abnormal process or instrument conditions.
9. Provide failsafe features such that instrument or computer malfunctions are detected, alarmed, and prevented form affecting the process.
10. Control the fuel and air to the reformer furnace.
11. Maintain a specified steam-to-dry gas ratio at the exits of the secondary reformer and the CO converter.

FIG. 1.





MONSANTO'S
COMPUTER CONTROLLED
AMMONIA PROCESS

Computer Manipulates These Ammonia Production Units

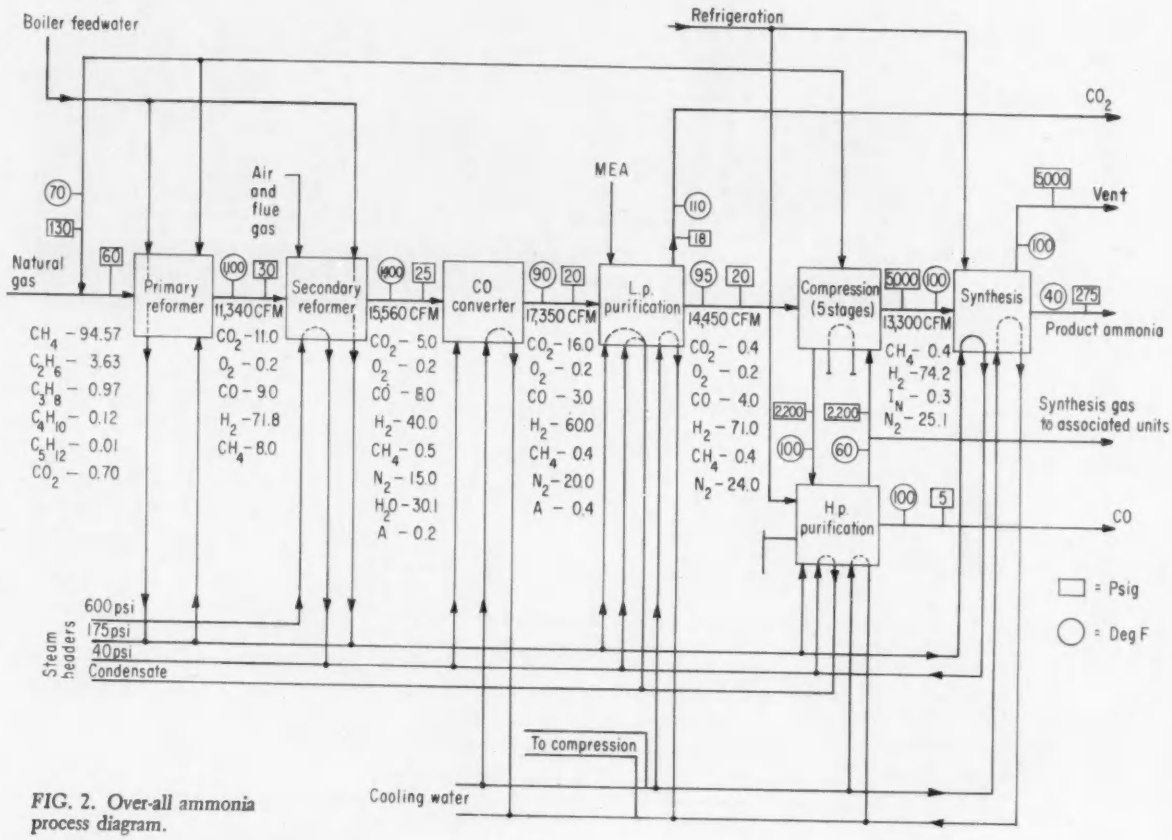


FIG. 2. Over-all ammonia process diagram.

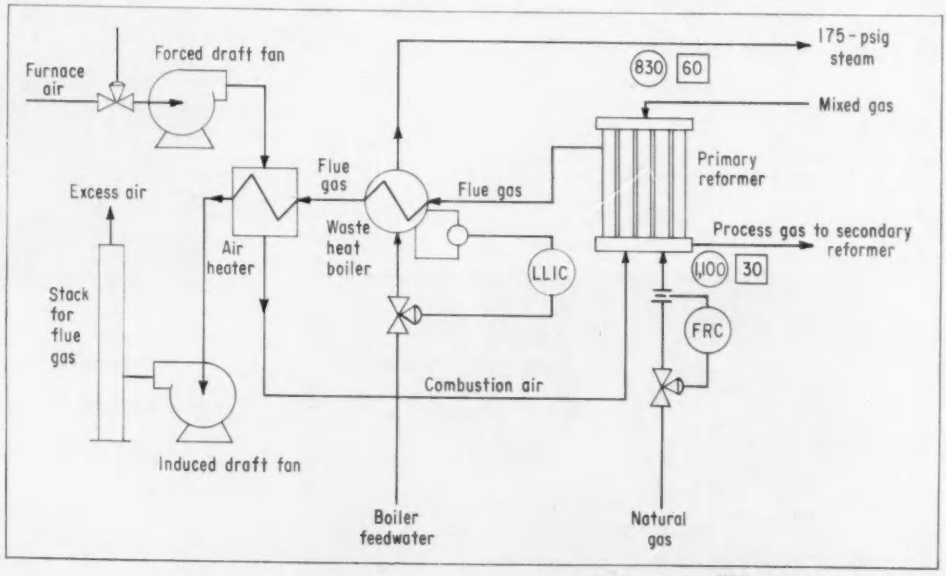


FIG. 3. Primary reformer.

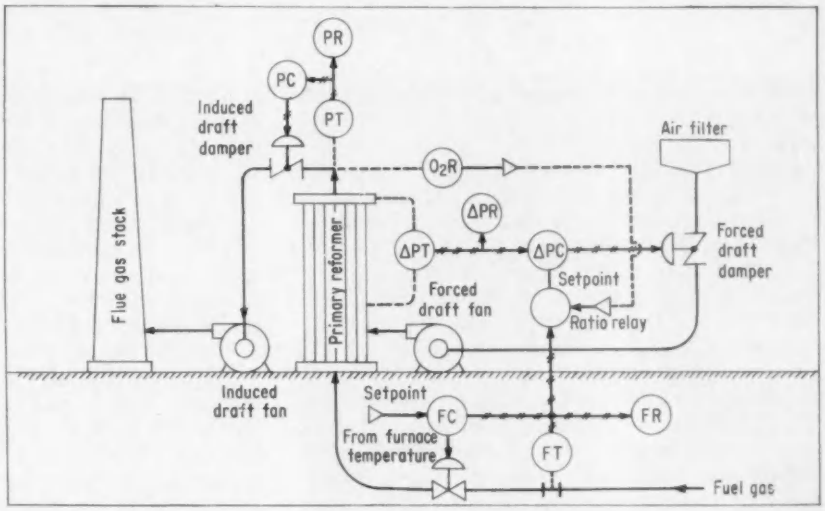


FIG. 4.
Primary reformer furnace combustion control.

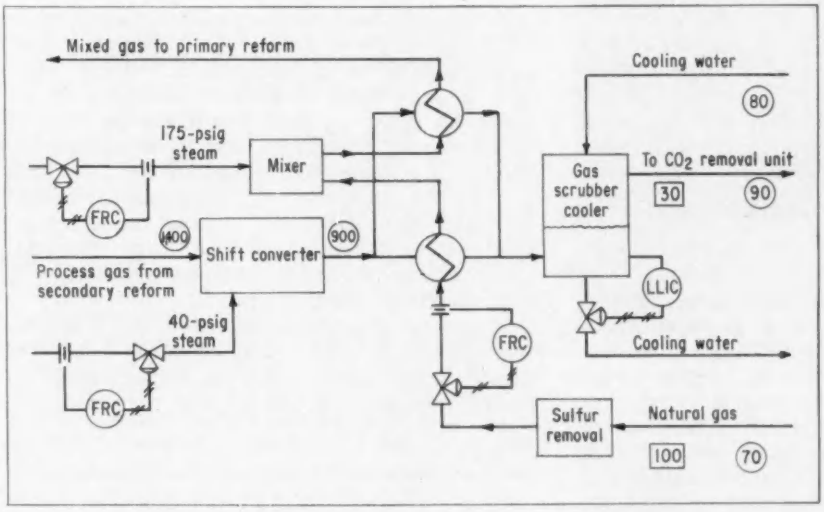


FIG. 5.
CO converter.

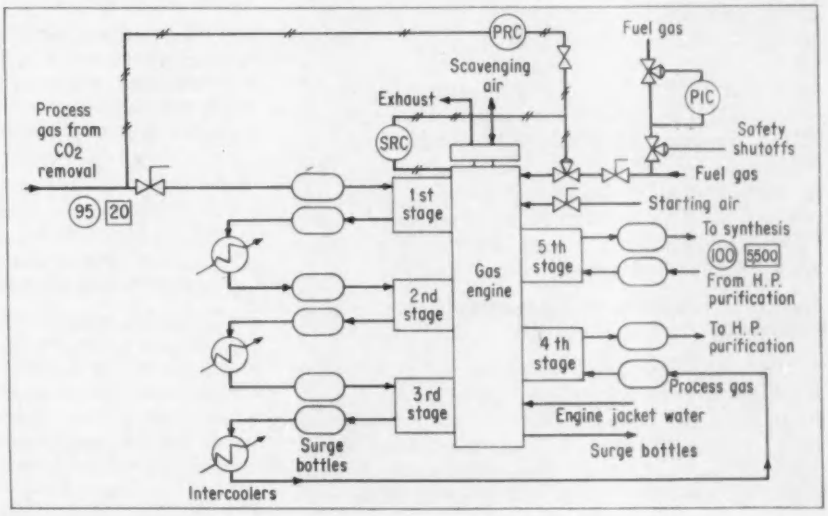


FIG. 6.
Compression system.

copper ammonium formate solution absorbs CO, and another absorber using a solution of ammonia in water removes the last CO_2.

The synthesis reactors are the vessels in which the ammonia product is formed. Product ammonia is condensed and separated from the reactor effluent by refrigeration. The unreacted gas returns to the reactors for further reaction along with the incoming flow. A small vent stream taken from the recycle stream prevents the buildup of such inert materials as argon and neon.

The synthesis unit should be operated at its design pressure and temperature and fed the correct proportion of hydrogen and nitrogen. The chemical equation, above, indicates a ratio of 3 to 1. However, pressure and equilibrium considerations alter this somewhat and maximum conversion is attained with a slightly different ratio. The exact ratio value varies from plant to plant and must be experimentally determined.

In practice the feed ratio to the synthesis reactors is maintained by regulating the H_2 to N_2 ratio at the exit of the shift converter. Because of the different solubility of the gases in the product ammonia, the shift-converter exit ratio may not be exactly 3 to 1. It too varies from plant to plant.

Developing the mathematical model

The mathematical model of the ammonia process stored in the computer provides the basis by which the computer oversees plant operation and returns the plant to the desired operating conditions should its performance deviate from optimum. The computer controls on-line, in that an operator is not required to translate the computer's findings into plant process changes. However, the computer exercises supervisory rather than dynamic control, since process corrections are made by the computer's altering setpoints of conventional plant instruments, Figure 1, rather than changing valve settings directly.

The model provides first for taking measurements and computing the desired values of major process factors in ammonia production, Table II. These desired values are then used as the basis for calculating the setpoints of the plant flow quantities, Table III. The model also includes the equations for reformer furnace combustion control as well as for a slow modification of the model for computing some of the process parameters should the original model not exactly follow the physical system. The spread, pages 110-111, details the development of the ammonia plant mathematical model.

Using plant data for process characterization

Most relationships involved in developing the mathematical model are empirical and are not derived from theoretical considerations. Thus the procurement of accurate plant data occupied a significant part of the work expended during the study. Regular plant log sheets were used wherever possible, particularly in developing those factors that reflect the seasonal variations of the plant's operation and dependence on ambient temperature conditions. Sometimes special plant runs were made to obtain sufficient data for a particular correlation.

Certain control constants were determined by trial and error adjustments after the computer was installed and operating. Actual forms of the control equations themselves were altered under operating conditions when plant results showed the desirability or necessity for such action.

The actual computer model used is therefore one which has been tailored to the Barton plant ammonia unit and as such is uniquely capable of controlling that unit. It will be in a state of evolutionary development as finer adjustments are made both to the process and to the control constants.

Revising plant instrumentation

Deriving the mathematical model for control of the ammonia process at Luling clearly indicated those variables which had to be measured. While in most cases it was possible to measure these variables directly, for measuring mass flow it was necessary to install pressure transducers and thermocouples upstream of the volume-flow primary elements. For each mass flow required, corresponding pressure, temperature, and orifice differential pressure measurements were sent to the computer. The digital computer, using standard correction formulas, calculated the mass flow from these inputs.

Process gas chromatographs were installed to analyze streams for the desired components. At the plant's reform section one gas chromatograph is shared between two points. The chromatograph

TABLE II
BASIC MEASURED AND COMPUTED VARIABLES IN REACTION OR SYNTHESIS SECTION OF AN AMMONIA PLANT

- Desired synthesis gas feed rate
- Hydrogen-to-nitrogen ratio at synthesis reactors
- Hydrogen-to-nitrogen ratio at CO converters
- Fuel gas composition at CO converters
- Secondary reformer temperature

TABLE III
SEVEN PRIMARY FLOW VARIABLES IN THE GAS PREPARATION SECTION OF AN AMMONIA PLANT

- Reaction gas flow to primary reformer
- Air flow to secondary reformer
- Flue gas flow to secondary air blower
- High pressure steam flow to primary reformer
- Low pressure steam flow to CO converters
- Fuel gas flow to primary reformer furnace
- Fuel-to-air ratio of primary reformer furnace.

switches between the two streams automatically and retains the data from the previous analysis until the computer is ready to use the information. The computer program initiates a request for stream analysis as required by the computation cycle of the process control equations. Another gas chromatograph, installed in the synthesis area, operates in a similar manner.

An oxygen analyzer controls primary reformer combustion efficiency by measuring the oxygen content of the flue gases leaving the reformer furnace. The computer reads data from each stream as required and calculates the proper ratio of fuel gas to combustion air. The computer then sets the control point of a ratio controller and switches the analyzer to the other stream.

Operating under three different modes of control, the two chromatographs and the oxygen analyzer:

- cycle between measured gas streams under computer control,
- cycle by themselves when not under computer control and indicate the analysis to the plant operator,
- analyze composition of any selected gas stream on a continuous basis.

Since the Barton plant was built prior to the advent of electronic control systems, the existing pneumatic control equipment had to be made compatible with the computer system. Those variables expressed as 3 to 15-psi pneumatic signals were converted to compatible electrical signals. Likewise, computer outputs have been converted to 3 to 15-psi signals for changing the setpoints of controllers.

Those existing controllers to receive computer setpoints were converted from having local position setpoints to having remote pneumatic setpoints. The modification was done in stages. Since plans called for adding four new control loops to the process, four new controllers with remote pneumatic setpoints were purchased. Four existing controllers were removed from operation and the new ones substituted. Then the old ones were modified to become remote pneumatic setpoint controllers, and these in turn replaced other controllers to be converted. This procedure continued until all controllers to be connected to computer outputs had remote pneumatic setpoints.

In addition to preparing the controllers for pneumatic setpoints, it was necessary to install subpanels below each controller to receive a computer output, Figure 7. This was done to provide a station where three general modes of control: *computer, automatic, and manual* of each variable could take place. Under *computer* control the pneumatic setpoints from the computer feed through the subpanel directly to the controller. Under *automatic* control the operator seals off the computer signal and establishes the required setpoint of the controller locally. Under *manual* control the operator manipulates the valves directly from the subpanel.

The subpanels also contain mercury switches which signal the mode of control to the computer. These

(*This text continued on page 112*)

FIG. 17. Newly installed subpanels below recording controllers aid communication between computer output and controller setpoint.

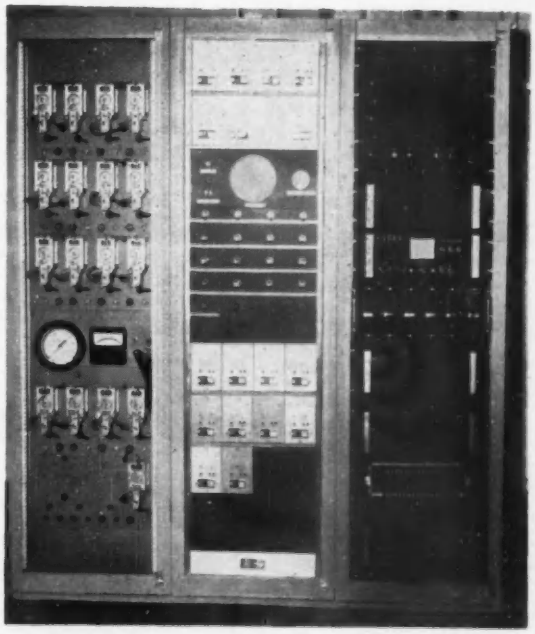


FIG. 8. Input-output equipment for Monsanto's control computer.

The Luling ammonia process mathematical model is tailored specifically for that plant. It is based on the results of extensive operating and special plant records, the data from which was reduced by regression analysis to develop the computer programs comprising the main-process control equations and the reformer furnace combustion control equations.

Figure 9 provides the over-all outline of computer control of the ammonia process. This figure, supplemented by the symbols, Table IV, proves useful in interpreting the equations characterizing the computer control scheme.

Main-process control equations

While there may be a tendency to overdesign some plant equipment, an engine-compressor system is usually conservatively sized because it represents a major fraction of the capital cost of an ammonia plant. The engine-compressor system is thus likely to be one of the first units to bottleneck the plant as production increases. At Luling the highest possible production rate and therefore the maximum economic return is obtained by operating the compressor system at maximum possible capacity. Due to the very definite influence of ambient conditions, particularly temperature, on internal combustion engine-compressor efficiencies, the allowable horsepower to be expended by the compressor follows a curve similar to that of Figure 10.

Total horsepower is regulated by adjusting the gas flow to the synthesis reactors. One of the computer's tasks, then, is to calculate the allowable flow of synthesis gas for the horsepower available and then regulate flow at this value. (Total required flows less than the maximum allowable can be handled in a similar manner if desired.) Allowable flow Q_s is computed by an empirical equation specific to each type of compressor:

$$Q_{s\,hp} = f(m, hp, X, T_I, P_S, P_I)$$

The limiting $Q_{s\,hp}$ is then compared with the corresponding desired production gas flow rate Q_{sd} and the smaller of these chosen as the Q_s for plant control. When the new calculated Q_s differs from the Q_s currently existing in the plant, the plant Q_s control must be altered to bring the plant in line. Due to plant inertia a limit exists on the rate at which gas flow change can be accomplished. The computer calls for change in flow rate from the smaller of two choices: If the magnitude of the called-for change is relatively small, the computer makes step-change corrections according to:

$$Q_{S\,new} = Q_{S\,old} + (Q_{S\,new} - Q_{S\,old})$$

However, if the change is relatively large, the computer limits the rate of change by employing the equation:

$$Q_{S\,new} = Q_{S\,old} \pm mk_1$$

where the sign of mk_1 is the same as the sign of $(Q_{S\,new} - Q_{S\,old})$, and k_1 is some limiting rate of compressor volume change. The factor m, the number of compressors on line, allows the computer to automatically account for compressor failure or the availability of additional compressor capacity.

Since the carbon dioxide is removed from the synthesis gas stream after the converter, the total gas flow will be somewhat different at the shift converter. The H_2 to N_2 ratio in the gas from the shift converter is symbolized as μ_{CR}. The H_2 to N_2 ratio at the synthesis unit, used as the composition ratio, is μ_{SR}.

The method established for correcting the μ_C to counteract upsets in the synthesis converters is:

$$\mu_{Cd} = \mu_{C\,old} + k_2\{[3.1 + k_3(2.6 - \mu_{SR})] - \mu_{CR}\}$$

The actual values of k_2 and k_3 depend on process dynamics.

Figure 11 presents a correlation, curve 1, of unreacted feed gas content in the converter effluent versus the reaction temperature in the secondary reformer. This curve is linearized, curve 2. The experimentally determined slope of curve 2, B_R, corrects the stored value of the slope:

$$B_d = \frac{B_{old} + k_5 B_R}{k_5 + 1}$$

Knowing B_d, the natural gas content

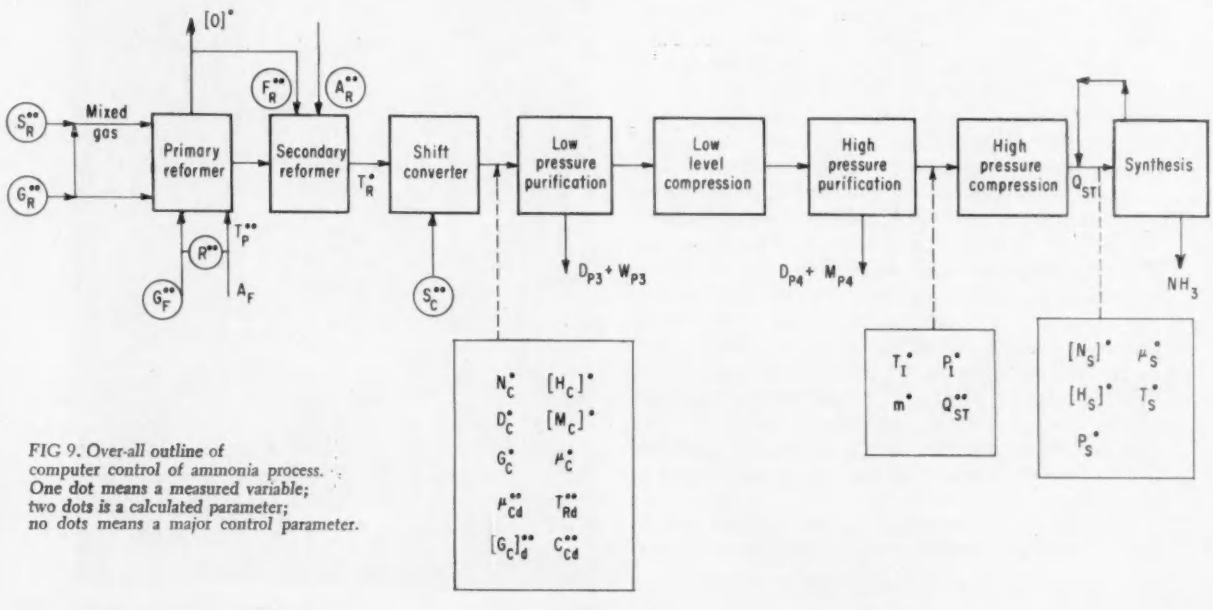


FIG 9. Over-all outline of computer control of ammonia process. One dot means a measured variable; two dots is a calculated parameter; no dots means a major control parameter.

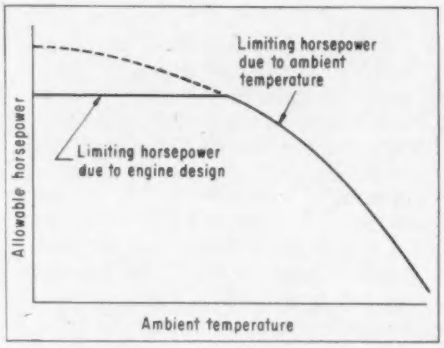


FIG. 10. Effect of temperature on allowable horsepower.

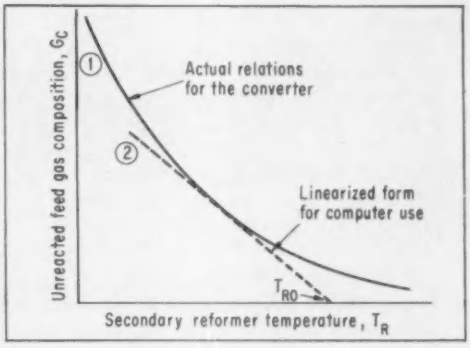


FIG. 11. Relationship of secondary reformer temperature and feed gas conversion efficiency.

$[G_C]$ is calculated, thus freeing the computer from dependence on analytical instruments:

$$[G_C]_d = B_d(T_{RO} - T_R)$$

and similarly, the desired secondary converter temperature becomes:

$$T_{Rd} = T_{R\,old} - k_9(k_7 - [G_C]_d)$$

Desired carbon dioxide to total carbon ratio after conversion

The actual carbon dioxide to total carbon ratio C_C corrects the desired ratio as follows:

$$C_{Cd} = \frac{C_{C\,old} + k_{10}C_C}{k_{10} + 1}$$

With the computed desired values listed above now available, the computer is ready to make the necessary calculations to obtain the optimum flow rates of feed gas G_R, steam S_R, air A_R, and flue gas F_R.

A set of three algebraic equations solved simultaneously by the computer gives the correct values for G_R, F_R, and A_R to attain the desired maximum production. The equations are:

• Total flow equation—

$$(3n + 1)G_R + 0.372A_R + \left[\frac{0.372R + (3n + 1)}{R - \frac{(n + 1)}{2}}\right]F_R = Q_S$$

• Converter H_2 to N_2 ratio—

$$[(2n + 1) + nB]G_R - (0.42 + 0.78\mu_C)\,A_R - \left[\frac{1.20R - (3n + 1)}{R - \frac{(n + 1)}{2}}\right]F_R = 0$$

• Secondary reformer heat balance equation—

$$\left[(2n + 1) + \frac{S_{R\,old}}{G_{R\,old}}\right]Z_1G_R + (0.79Z_1 - 0.915T_A - 5{,}736)A_R + (0.975Z_1 - 0.915T_A - 683)F_R = 0$$

where:

$$Z_1 = (T_{Rd} - 1.05Z_3T_{PR} + 11{,}642Z_2Z_3)$$

$$Z_2 = \frac{1}{1 + q}\exp(10^{-3}G_R - 6.70)$$

$$Z_3 = \frac{(2n + 1)G_R + S_R}{Q_R(1 + 2nZ_R)}$$

and q can be arbitrarily taken as 0.59.

• Steam flow to primary reformer equation—

By an empirical relationship, the required steam flow to the primary reformer can now be calculated:

$$(S_R/G_R) = 0.42K_1(A_R/G_R) - 0.363(A_R/G_R) + 5.77K_1 - 0.4(K_2K_1) - 0.21K_2 + 1.30$$

where

$K_1 = (W_R/Q_R)$ desired, and K_2 is the reciprocal of the equilibrium constant of the water-gas-shift reaction at T_C.

• Steam to shift converter—

Meanwhile, S_C is calculated by:

$$S_C = W_C - S_R + (1 + C_C)n\bar{G}_R - 0.419\bar{A} + \frac{(n + 1)F_R}{\left(R + \frac{(n + 1)}{2}\right)}$$

Here: $\bar{G}_R = G_R + \dfrac{F_R}{R + \frac{(n + 1)}{2}}$

and $\bar{A}_R = A_R + \dfrac{RF_R}{R - \frac{(n + 1)}{2}}$

Furnace combustion control equations

With all reactant stream flow rates calculated and ready to be used to reset the setpoints of flow controllers, only one more relationship remains to be calculated—the reformer furnace fuel and air control point. The fuel flow is:

$$G_F = k_{10} + k_{11}S_R + 2.65G_RT_F - K_{12}(S_R + 2.65G_R)S_R/2.65G_R$$

The desired fuel-to-air gas ratio is:

$$R_d = \frac{2.085 - 1.03[O_F]_d}{0.2095 - [O_F]_d}$$

where

$$[O_F]_d = 0.192 - 2.03 \times 10^{-4}G_F - k_{13}[O_F]_{old} + k_{14}[O_F]_R$$

These empirical relations allow the most efficient combustion possible and adjust the total fuel flow to provide the desired operation of the primary reformer.

TABLE IV
SYMBOLS EMPLOYED IN DEVELOPING MATHEMATICAL MODEL

A	Total air flow; its subscript indicates location
B	Slope of unreacted gas vs reformer temperature curve
C	Carbon dioxide to carbon monoxide ratio; as subscript, indicates shift (or CO) converter
D	Carbon dioxide flow
E	Efficiency of conversion of feed gas to hydrogen
F	Flue gas flow to reformer; as subscript, indicates reformer furnace
G	Natural gas flow
H	Hydrogen gas flow from converter
I	As subscript, indicates inlet of compressors
K	Desired water content of reformer gas or reaction equilibrium constant
M	Carbon monoxide flow
N	Nitrogen gas flow
O	Oxygen
P	Pressure
Q	Total gas flow
R	Fuel-to-air ratio in reformer furnace; as first subscript, refers to reformer; as second subscript, refers to measured value of variable
S	Steam flow; as subscript, refers to synthesis unit
T	Temperature; as subscript, total amount
W	Water flow
X	Fraction of reaction gas actually sent to synthesis
Z	Empirical factors in simultaneous equations for flows in process
d	As subscript, desired value
k	Arbitrary constants
m	Number of compressors on line
n	Number of carbon atoms in the formula C_nH_{2n+2}. For hydrocarbon fuel gases $n \cong 1.05$
q	Ratio of steam to dry gas at exit of primary reformer
3	As subscript, refers to low pressure purification unit
4	As subscript, refers to high pressure purification unit
hp	Horsepower
[ ]	Indicates composition when used around any symbol
μ	Ratio of H_2 to N_2

one-bit inputs from the subpanels are programmed so that portions of the process control calculation will not be made unless the proper variables are connected to the computer via the *computer* or *automatic* mode. Thus in *manual* operation the computer acts only as a data logger.

The input-output equipment to the computer system is housed in three cabinets, Figure 8. The input equipment, center cabinet, contains transducers which convert the existing 3 to 15-psi signals to dc signals compatible with the analog to digital converter in the computer. (For the four new pressure and flow instruments, process variable to direct current transducers are used.) The center cabinet also contains a junction box for all high level pneumatic analog inputs. All temperature measurements required by the computer enter the system through this cabinet but are then connected into the thermocouple input section in the upper right cabinet.

The output equipment, left cabinet, contains the transducers for converting the computed electrical analog signals from the computer to 3 to 15-psi setpoints for the pneumatic controller. This cabinet also contains emergency cutoff and interlock equipment to seal the pneumatic outputs at their last valid value should the computer system fail. Both the input and output cabinets contain built-in calibration stations for checking transducers and simulating variable values for test work.

A group of alarms tells the operator quickly where failures occur in the system and directs his attention to their correction. To accomplish this, different types of audible alarms are placed in or near the affected equipment. As examples, existing process troubles sound a horn behind the main instrument panel, a bell installed in the input-output equipment indicates alarm condition in this area, and a buzzer in the computer operator's control console warns of alarm conditions in the computer or its program. Wherever possible such alarms are backed up with interlocks or emergency procedures. In the case of program-failure alarms, the last valid readings or predetermined values are used by the computer in its calculations.

Installing the computer system

Not enough can be said for using care and extensive planning when installing such a complex computer control system. Some basic ground rules were established by the Monsanto-TRWP project team. The installation had to be neat and orderly, and with this in mind, the decision was made to use cabling wherever possible. The cabling now runs in adequate conduits, sized for ease of installation and possible system expansion. In the control room, conduits are located in the floor; the wires then pass upward to allow easy access to the bottom of the equipments.

All analog inputs pass through the computer system pneumatic input panel, providing a convenient place to check and simulate each analog input. In the computer system output panel, all electrical outputs connect to a terminal strip where checks and simulations are made to prove the system.

All electrical one-bit inputs to the system terminate in the oxygen analyzer control cabinet located in a motor control room adjacent to the main process control room. From this point the digital input wires are cabled through the conduit to the computing equipment, again providing a convenient location for checking and simulating.

In many cases ac pickup from other electrical equipment occurred on the dc signals to the computer's analog to digital converter. While it is difficult to predict the magnitude of such pickup until the installation nears completion, correction of pickup is quite simple and is no real problem in installation. Wherever pickup occurred on a signal line, an *RC* filter network was inserted.

Besides a separate power supply for the process analyzers and the computer and its associated equipment, a constant voltage transformer and an electrostatically shielded transformer are installed on the power line to the computer; the latter transformer rejects transients caused by other electrical units.

Since the computer inputs are direct currents (which appear across precision resistors for voltage measurement) and voltages, a true signal ground is mandatory for the system to be free of ground loop problems. A separate ground bed was installed, and from this bed an adequate metallic ground connection to each piece of equipment prevents such errors.

The actual installation of the computer, computer operator's control console, and computer analog input-output panel took only a few days. Prior to this, adjustment and calibration of field-mounted equipment had been completed, Figure 12. The first day

FIG. 12. Calibrating and adjusting field mounted control devices.

after the computer arrived the equipment and most of the cables interconnecting the equipment were installed. Quick disconnect devices on most cables simplified new equipment interconnection, although some time was consumed making connections between the computer and existing control equipment.

Each input and output to the computer was checked for compatibility. Such things as voltage, current range, and polarity had to be checked with the system installation completed—a slow, time consuming, but necessary operation.

Operating tests of computer programs

TRWP first loaded test programs—the same ones used in computer checkout prior to shipment—into the computer to test all functions within the machine. Knowing the results of these tests beforehand, TRWP could determine transportation effects.

The next step was to load the computer with different sections of the prepared program—one at a time. Each section of the program was cycled and checked. The first objective was to get the data logging system in operation. While the data used in developing the mathematical model had already been obtained from operating records prior to an expansion program (which was completed before the computer went on stream), it was necessary to obtain accurate, reliable data from the logging system to further verify the mathematical model and make required minor changes before going on control.

Along with the data logging system, instrument scanning and alarm programs were started. These programs, designed to test each piece of input data prior to usage in the process control program, were based on predetermined limits of validity established from process and operating data.

After loading the complete program into the machine, the outputs were turned on and allowed to go as far as the instrument subpanels. Each subpanel indicates both the computed output and the setpoint of the associated controller, making it possible to track the computed output by having the operator line up the two indicator points.

Putting the computer on stream

Basically there are two control programs. The main process control program adjusts the flow of raw materials to the process. The combustion control program adjusts the ratio of combustion air to fuel for the primary reformer. These two programs are interrelated because the required heat input to the reformer is determined from process flow conditions. Initially, tracking the ratio setting of the combustion control system was tested with the operator controlling heat input to the furnace. After tracking the computer outputs for several hours, Figure 13, the engineers became confident of the combustion control program and the hardware associated with this portion of the computer control system. Finally, the computer outputs were connected through the subpanels directly to the controllers.

FIG. 13. Monsanto engineers Eisenhardt, Legendre, and Thurman watch results of computer program tryouts.

The same general procedure was used in placing the main-process computer outputs on control. The less important variables were picked first, tracked for several hours, and then placed on computer control.

The tracking operation provided an opportunity to observe the reaction of the control system. Changes in control equation constants were made from time to time to insure plant stability when all outputs were placed on computer control.

With this step-by-step procedure of tracking and adjusting accomplished, the complete computer control went on-line for a five-day test period. During this period system operation was observed, after which the computer was taken off control to make additional adjustments in the control program. Some program changes simplified computer functions. Since this initial test period the computer control system has been on line, serving both as a production-process control system and as a controlled-process tester.

What Monsanto gained from computer control

Immediately after placing the computer on control, the gains in controllability became evident. When the process is not on computer control the operator makes minor changes in controller setpoints—trying to hold process temperatures within limits and maintain gas composition as required by the synthesis loop. Superimposed on top of these minor changes are larger step changes in throughput which are required to compensate for those uncontrolled variables affecting plant capacity. At best, these larger changes are made only several times a shift. Under computer control, however, plant throughput is adjusted every 8 min to obtain maximum possible production as uncontrolled variables change. Qualitatively one can observe from the computer log sheet the steadying of gas compositions and temperatures under computer control—as compared with the irregular control obtained by even the best operator.

Another indication of gain in controllability—quan-

titative in nature—has been observed: a regression analysis of plant production data vs uncontrolled variables data indicates a standard error from best possible production of plus or minus 1 percent while under computer control. Standard errors in excess of 5 percent occur under operator control.

As of this time the plant has not been on computer control long enough to make an accurate evaluation of increased production. As previously pointed out, the ammonia process is affected quite radically by seasonal as well as daily atmospheric changes. Because of this a complete evaluation will be made after one year's operation. There are indications, however, that the Luling installation is equalling or bettering economic as well as technical expectations.

One unestimated economic gain will come from a better understanding of the process. This is possible because it is felt that with a computer control system, an era of controlled testing is being entered in addition to increased plant production capabilities. The derivation of the mathematical model has already indicated several areas for operations improvement. By the same token, expected improvement of the mathematical model as more plant data is obtained will no doubt indicate other potential benefits.

What Monsanto plans next

In the area of controlled testing of the Luling installation, Monsanto plans to investigate such things as varying the composition of the gas to the synthesis reactor since little is now known as to what the best inlet composition is for a given catalyst operating at a given temperature and pressure. Another possible test would determine the correct economic value of methane leaving the reforming area. Such a test is now possible because controllability using the computer has improved to the stage where the effect of small changes in controlled variables can be observed on such trace-component items as methane.

Finally, it is important to remember that the computer does not handle the dynamics of each control loop but exercises control over the entire plant by setting the control point of each controller. The key to further payout lies in the ability to refine and increase the usefulness of the mathematical description—perhaps by including process dynamics in the computer-stored process model.

Computer systems team and its training

The design and installation of a process control computer system requires the talents of many specialists, Table V. Since a complete understanding of the ammonia process is of first importance, a plant process engineer acquainted other team engineers with the process basics. Also, since individual control loops were to retain physical control of the process, the team included a process control engineer from Monsanto's Inorganic Division Engineering Dept. Plans called for the new equipment to be installed while the plant was in operation. Therefore, a plant construction engineer—experienced in instrumentation, electrical systems, and the ammonia plant—was assigned to supervise this phase. The project engineer, moreover, had to be familiar with all three phases and have broad understanding of digital computer and systems engineering techniques.

TABLE V
TEAM MEMBERS OF THE
MONSANTO-TRWP COMPUTER PROJECT

● Monsanto Chemical Co.:	
Inorganic Chemicals Div.—Engineering	
W. Du Puy	Process Engineer
R. D. Eisenhardt, Jr.	Project Engineer
C. L. Parish	Assistant Director
Inorganic Chemicals Div.—Luling Plant	
F. W. Lange	Plant Supervisor
G. S. Legendre	Process Engineer
C. Ohms	Process Engineer
C. H. Thurman	Construction Engineer
T. A. Williams	Plant Supervisor
Research and Engineering Div.—Engineering	
R. E. Lenz	Assistant Director
G. E. Russell	Systems Engineering Manager
M. Welhoelter	Technologist
T. J. Williams	Engineering Supervisor
● Thompson-Ramo-Wooldridge Products Co.:*	
R. P. Adams	Project Engineer
E. Borgers	Chief Computer Programmer
D. L. Fellows	Computer Programmer
R. C. Johnson	Process Study Engineer
C. G. Laspe	Process Study Engineer
J. L. McLaughlin	Process Study Engineer

* Now TRW Computers Co.

Once the computer was purchased, the next step was to train the Monsanto team members in the details of the particular computer system to be used, RW-300 digital computer. At first all Monsanto engineers received identical training, but as the project progressed the training for each member became more specialized. The project engineer learned about the general application of the computing equipment to the process. He had to consider such things as functions to be performed by the plant operator, the design and compatibility of the peripheral equipment not supplied by the computer maker, and the over-all project requirements and goals. The process engineer concerned himself with initial, detailed computer programming. Furthermore, once the system was installed and working, he would be required to make the necessary program changes as additional operating information became available to improve the mathematical model. Computer programming is an important and continuing function. Therefore the construction engineer, who would also be responsible for computer maintenance for which programming knowledge is needed, was selected for training as the backup programmer. As part of the training program, TRWP provided four to six-week courses in programming and in the theory of computer operation.

Don't overlook POSITIVE feedback

THE GIST: If requirements for simplicity, small volume, light weight, and low power consumption dog your engineering of control function circuits, this reexamination of positive feedback can help you. Use of transistors in practical circuits presented by the author offers the additional advantages of low output impedance, minimum number of amplification stages, and elimination of dc coupling from output to input.

"But positive feedback systems are more apt to oscillate," you say—not if you study the author's theory and follow his translation to practice.

WILLIAM SCHARF
Aeronautical Division
Minneapolis-Honeywell Regulator Co.

When doesn't the stability analysis of control systems indicate the need of dynamic compensation in order to achieve required over-all system frequency response and gain and phase margins? Hardly ever. How often is the control system designer able to fix the compensation parameters at the beginning of a control system design problem? Seldom, if ever. Initially the form of dynamic compensation is selected, but numerical values of the compensation scheme remain fluid until more detailed dynamic information is obtained. In the development of an automatic flight control system, for instance, the fluidity extends through flight test. Clearly, a flexible compensation scheme is necessary. Either active or passive compensation will work. If passive, the system designer pays the price of additional amplification for the inherent attenuation. If the initial analysis calls for second-order underdamped compensation, only with an active circuit will resistors and capacitors meet the requirement.

Active compensation fills the bill when great flexibility, lack of attenuation, and limitation to noninductive elements are required. An active filter using positive feedback realizes, in addition, the necessary low-frequency open-loop gain of lead/lag compensation. A stable low gain transistorized differential amplifier is the active building block around which the variety of active networks may be built.

Lead/Lag function

If the required lead/lag ratio is 2/1 or less, and if the available signal level can be attenuated, a passive network is quite adequate. Or, if a phase-sensitive signal is desired, negative feedback generation of lead/lag in an active circuit is all right. Otherwise, positive feedback generation should get serious consideration.

Figure 1A shows block diagrams of negative and positive feedback arrangements for active generation of a lead/lag control function. A lag in the negative feedback path generates a closed-loop lead action. A derivative network in the positive feedback path produces the same closed-loop action. Amplitude-frequency plots, Figure 1B, of Equations 1 and 2 in the figure demonstrate the inherent advantages of the positive feedback arrangement:

- Realization of unattenuated forward loop gain at low frequencies
- High frequency (at 180 deg phase shift) gain dependence on the lead/lag ratio

In the negative feedback arrangement the lead/lag ratio attenuates the forward loop gain at low frequencies. In fact, the greater the lead/lag ratio, the lower the low-frequency gain. Open loop gain of the amplifier is realized at only high frequency, a performance similar to that of a passive RC lead/lag network. The big disadvantage of the negative feedback circuit is that the open loop gain must be at least 20 times the closed loop gain, to attain 5 percent accuracy. Because of the high gain the design must incorporate networks that will prevent both low and high frequency oscillations, which somewhat defeats the negative feedback technique.

Figure 2A shows a transistorized positive feedback circuit that generates the lead/lag function. The in-phase signal passes through a derivative network and

is algebraically summed with the input signal, e_f. If a push-pull collector stage is required, the optional stage shown is added to eliminate loading. Should the optional stage be used as an amplifier, i. e., with common emitter configuration, the input to the stage is taken from the collector of the summing transistor. Because the transistor time constant is negligible below 100 kc, its effect is omitted. Equations describing the circuit shown in Figure 2A are:

$$e = \left[\frac{e_i(R_f + R_2) + e_f R_s}{R_f + R_s + R_2}\right] \frac{R_i}{R_i + R_{eq}} \tag{3}$$

$$e_o = \frac{\beta R_s}{R_i}\, e \tag{4}$$

Combining 3 and 4,

$$e_o = \frac{R_f + R_2}{R_f + R_2 + R_s} K_1 \left[e_i + \frac{R_s}{R_f + R_2} e_f\right] \tag{5}$$

where α = current transfer ratio

$$\beta = \frac{\alpha}{1 - \alpha}$$

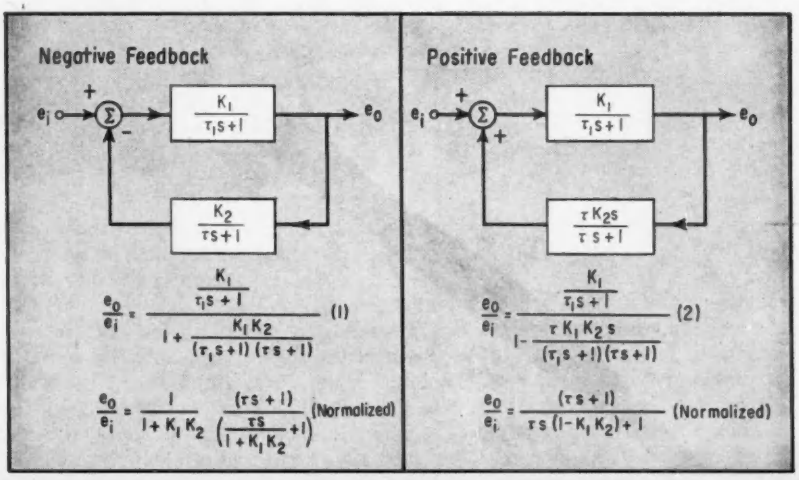
R_i = transistor input resistance

$$R_{eq} = \frac{R_s(R_f + R_2)}{R_f + R_2 + R_s}$$

THEORY

FIG. 1. A—Block diagrams of active lead/lag function generation by positive and negative feedback. B—Comparison of frequency responses for lead/lag ratios of 10/1 (solid curves) and 5/1 (dashed curves).

A.



B.

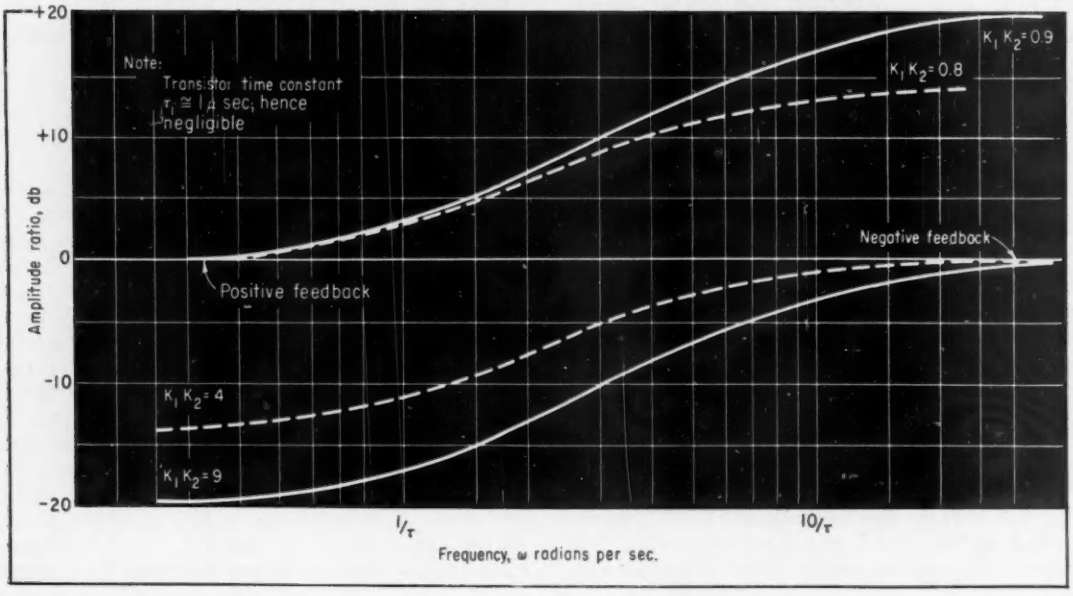
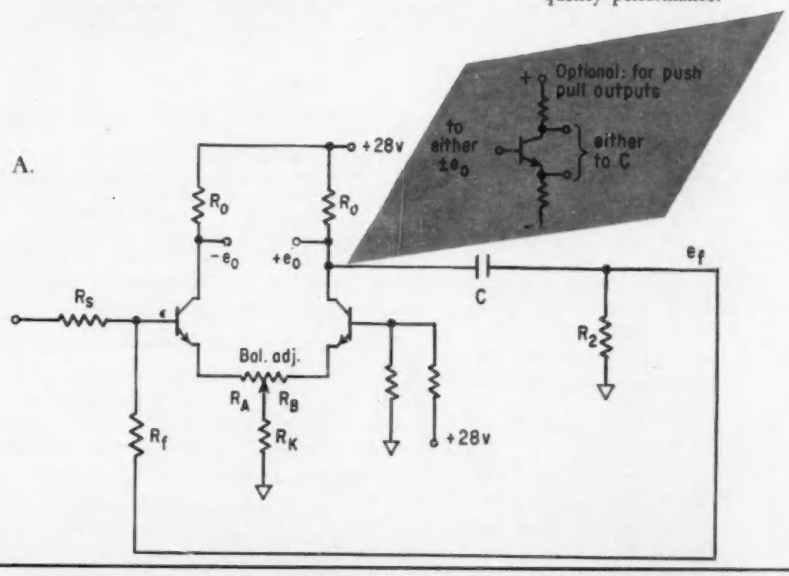
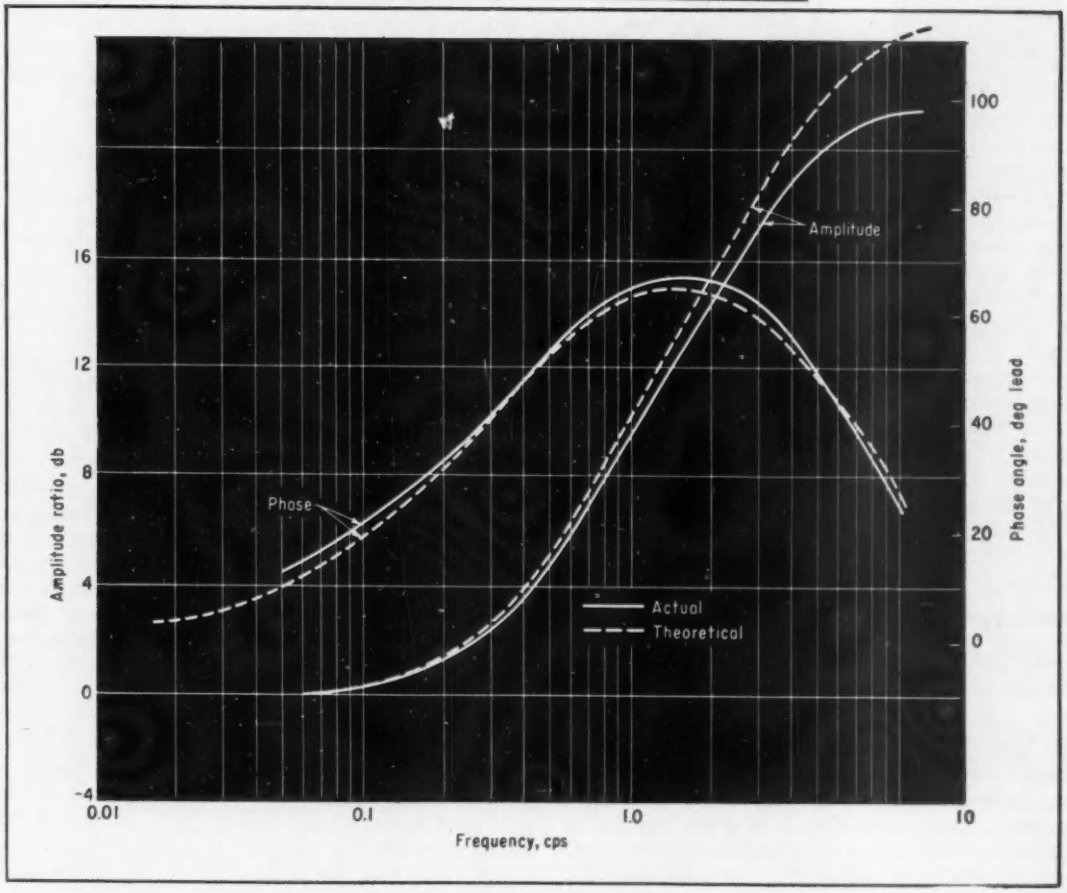


FIG. 2. A—Transistorized positive feedback circuit for lead/lag function. B— Actual vs theoretical frequency performance.



B.



$K_1 = \frac{\beta R_o}{R_i + R_{eq}}$, amplifier gain, including source resistance effect.

Solving for e_f in terms of e_o,

$$e_f = \frac{\tau K_2 s}{(\tau s + 1)} e_o \tag{6}$$

where $K_2 = \frac{R_2}{R_2 + R_o}$ and $\tau = (R_2 + R_o)C$

Combining 5 and 6,

$$\frac{e_o}{e_i} = \frac{K_1 \frac{R_f + R_2}{R_f + R_2 + R_s}(\tau s + 1)}{\tau s\left[1 - \frac{K_1 K_2 R_s}{R_f + R_2 + R_s}\right] + 1} \tag{7}$$

Equation 7 demonstrates that the lead/lag ratio is a function of the coefficient of the s term in the denominator. Typically $K_1 = 5$ and $(R_f + R_2)/R_s = 1$. Substitution of these values, division by the coefficient of τ s, and rearrangement to indicate the proportional and rate terms yields:

$$\frac{e_o}{e_i} = 2.5\left[1 + \frac{2.5K_2\tau s}{\tau s(1 - 2.5K_2) + 1}\right] \tag{8}$$

Equation 8 contains an important warning; instability occurs when K_2 equals or exceeds 0.4. It also shows that variation of the numerator break frequency depends on τ and that the lead/lag ratio depends on K_2. A practical means of varying K_2 and thus the lead/lag ratio is to use a potentiometer for R_2. The potentiometer also serves in adjustment for variation of commercial transistors. Capacitance C varies time constant τ. Figure 2B compares the actual frequency response with the theoretical response for a lead/lag ratio of 20/1.

Application of this network in a flight control system offers the possibility of eliminating rate gyros for the augmentation of aerodynamic damping, because the network can generate a rate signal from the attitude gyro signal. The break frequencies of Figure 2B indicate that the network can readily approach or exceed the response of the rate gyro that it replaces. Hence the lead/lag network satisfies system dynamic performance requirements, reducing the problem to elimination of amplifier saturation by noise. If additional noise filtering is required, a lag at three to five times the lag break frequency (5 to 25 cps) may be added. A control system using this technique materially reduces weight, volume, and cost.

Stability

Equation 7 shows that the circuit can oscillate if

$$K_1 K_2 \frac{R_s}{R_f + R_2 + R_s} \geq 1.$$

The second and third terms are resistance ratios. Because the resistors are 1 percent tolerance components and because their temperature coefficients are identical, the two terms contribute less than 1 percent variation in gain. Variation in the first term, amplifier gain K_1, is minimized by an external emitter resistor, which creates negative current feedback as does the cathode resistor in a tube circuit. Rewriting the expression for K_1,

$$K_1 = -\frac{\beta R_o}{R_{eq} + r_b + \frac{r_e + R_E}{(1 - \alpha)}}$$

$$= -\frac{\alpha R_o}{(R_{eq} + r_b)(1 - \alpha) + r_e + R_E}$$

where r_b = transistor base resistance = 250 to 350 ohms
r_e = transistor emitter resistance = 10 ohms at 2.5 ma
R_E = external emitter resistance.

Small variations in α cause large variations in $(1 - \alpha)$. In junction transistors α is typically between 0.9 and 0.99. Therefore, to stabilize the gain of a common emitter configuration,

$R_E \gg (R_{eq} + r_b)(1 - \alpha)$; effect of r_e is neglibible.

In the limit K_1 becomes $-R_o/R_E\ [\alpha_o + \Delta\alpha]$, indicating that variation in α is the chief effect on gain variation if the external resistors are precision components. If, for instance, Texas Instruments silicon transistors are used:

$0.9 \leqq \alpha \leqq 0.95$ (2N332)
$0.95 \leqq \alpha \leqq 0.98$ (2N333)

The 2N332 would result in a plus or minus 3 percent gain variation and the 2N333 a plus or minus 1.5 percent gain variation. R_E might be 10 times $(R_{eq} + r_b)\ (1 - \alpha_o)$, in which case the over-all gain variation with a 2N333 would be 5.5 percent.

More for the asking

Analysis of the compensation for space vehicles indicates the need of the transfer function of the form shown in Equation 9 to compensate for structural bending modes.

$$\frac{e_o}{e_i} = \frac{s^2 + 2\zeta_1\omega_n s + \omega_n^2}{s^2 + 2\zeta_2\omega_n s + \omega_n^2} \tag{9}$$

The damping ratios, ζ_1 and ζ_2, are both less than unity. A typical ratio of ζ_1/ζ_2 is 1/5. Required is a notch filter with unity gain at low and high frequencies and maximum attenuation when the driving frequency coincides with the natural frequency of bending. Only an *RLC* network will generate this function in a passive circuit. The dimensions of the *RLC* components will be large because of the low natural frequency of the system. An active negative feedback arrangement may be used, but because it will require an integrator in its feedback loop, it will be more complex than an active positive feedback arrangement.

The author has designed and proven positive feedback underdamped second order compensation. The amplifier is identical to that used in the lead/lag function generator. He has modified only the feedback filter. To receive complimentary copies of the author's notes on the theory and practice of his scheme, write to: The Editor, CONTROL ENGINEERING.

Using Electric Adding Machines as Cheap ADP System Components

Adding relatively inexpensive electromechanical input-output devices to common electric adding machines can turn them into very useful components for automatic data processing when operation times measured in seconds are fast enough. Effective automatic computers can be made for costs in the neighborhood of $1,000, for example, by coupling such equipment with a paper tape punch and reader for data storage. This article gives five applications in which electric adding machines can do all the calculating automatically at costs far below those for electronic systems.

J. F. SHARP
Bulmer's (Calculators) Ltd., London

FIG. 1. Electric input-output adding machines.

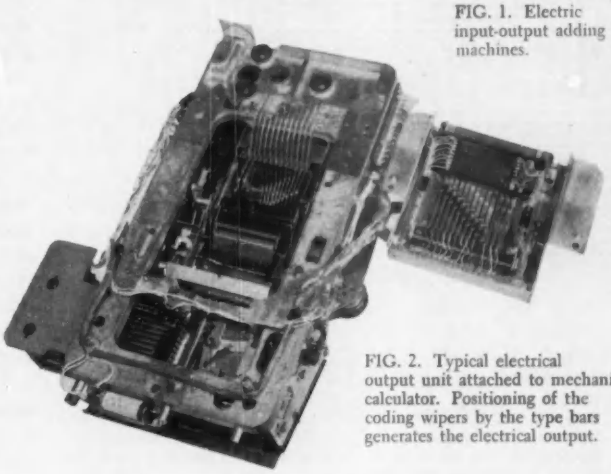


FIG. 2. Typical electrical output unit attached to mechanical calculator. Positioning of the coding wipers by the type bars generates the electrical output.

Modern digital printing calculators like those in Figure 1 all possess mechanisms which do simple arithmetic. Two separate quantities can be totalized by dividing a machine's mechanical register in two. Alternatively, one register can be used to record code numbers and the other to do the calculating, thus producing control totals for verification of results.

The addition of electric input-output devices to mechanical calculators opens up new possibilities of using them as cheap, simple automatic data processing system components, such as converters and stores. An "add-on" unit of 16 electromagnets with armatures on knife edge bearings is all that is required for electrical input. Each key normally available to the manual operator is then solenoid operated. A feedback contact is added to make each time a digit solenoid is energized and break when the solenoid is released. Another —the print contact—is coupled to the printing mechanism to close when a function solenoid is energized and remain closed until printing is completed. Other solenoids can be added to permit information to accumulate in the registers without print-out. Remotely controlled multiplication is possible by using a keyboard nonclear solenoid which allows numbers to be held in the keyboard and printed and recorded repeatedly, dependent on the number of times the plus or minus solenoid is energized. On two-register machines extra solenoids can give a choice of the register into which entries are made.

Figure 2 shows a typical electrical output unit attached to a mechanical calculator. Contacting wiper bars, actuated from the type bar mechanism, moving across a number of output bars, provide a digitized electrical output. The start of the printing cycle operates a lever to lift the coding wipers away from the output bars. As they release, the previous output is canceled and the wipers return under spring pressure to their zero rest position against the actuating level rollers on the type bars. Raising the type bars positions the wipers with respect to the output matrix, and the actual printing operation depresses the contact onto the matrix to lock them in their coded position, while the type bar themselves return to their rest position. After locking of the contacts, an impulse from a miniature switch on the adding machine motor shaft initiates the associated reading mechanism. Thus the machine provides two mechanical stores, one holding the present electrical output and the other holding the next.

FIVE WAYS OF USING ELECTRIC ADDING MACHINES FOR ADP

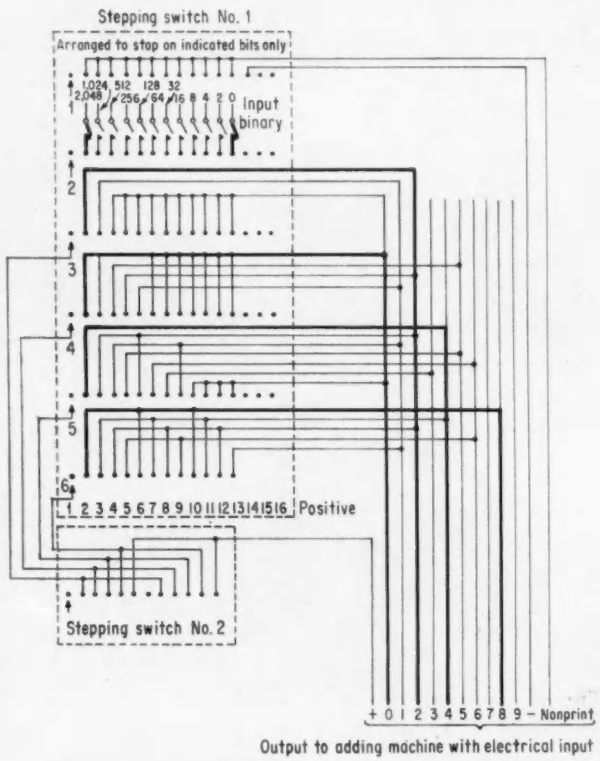


FIG. 3. First step on receiving a binary 100000000000 signal as shown is the stopping of stepping switch 1 on position 2. This starts stepping switch 2, sequentially reading into the adding machine the location values of the four wipers of stepping switch 1. Wiper 3 feeds in a two, wiper 4 a zero, wiper 5 a four, and wiper 6 an eight. As the machine decimal shifts after each input, the print out figure is the decimal equivalent 2,048.

1. Binary to decimal conversion

Two stepping switches added to an electrical input adding machine will produce a cheap binary to decimal converter capable of translating a 12-bit input to decimal output within 7 sec. The adding machine is first put in the "nonprint" condition by wiper 1 on stepping switch 1, see Figure 3. As wiper 2 starts scanning the binary source input, the first indicated binary bit completes an electric circuit to stop the stepping switch at this position. Stepping switch 2 now scans to locate the stopped position of the stepping switch 1 and reads off the decimal equivalent of this first binary bit. Actual decoding is accomplished by prewiring on the banks of stepping switch 1. This decimal equivalent of the first indicated binary bit feeds into the adding machine register but is not printed. After reading, stepping switch 1 continues advancing, sampling each bit in turn and, where necessary, decoding via switch 2 to accumulate the equivalent decimal numbers in the adding machine register. When the last bit has been scanned, the first wiper of stepping switch 1 automatically energizes the "Total" solenoid and deenergizes the nonprint solenoid. This immediately prints out the accumulated total in the register on either a 2¼-in. tally roll or as column tabulations on larger machines.

The cost of the adding machine converter ranges between $896-$1,652 depending on whether the basic unit is a standard tally roll or a long-carriage machine. In a comparable electronic system, cost would be approximately $2,100 for the binary to decimal converter unit alone.

2. Arithmetic unit for random access system

A random access store with access times of less than 2 sec can be had by using the mechanical registers in the adding machine as arithmetic units and coupling the adding machine to a drum memory.

Figure 4 shows a typical system, in which a four-digit nonadd code number is entered into the adding machine to form the address of a particular store on the drum. Circuits provide an immediate read-out of the contents of that store (either positive or negative), entering it through the electrical input unit into the adding machine. The operator next makes an entry (an issue or receipt, plus or minus) and totals the machine. The new total is immediately written back from the adding machine into the original address on the drum and the system freed for the next operation. Costs of such a comparatively simple data storage system are trifling compared with fully electronic computers.

Typical application of such a low cost data system is order picking for daily dispatch to branches of a chain store. Consignments for each branch, in standard size packets, are gathered every morning, and transportation is allocated in late afternoon. The truckloads of consignments leave the depot during the night. Using an adding machine-drum random access store, a 10-digit store on the drum is allocated to each branch. The store adding machines have their registers split to total on one side the weight of the packages and on the other the total of packages as a three-digit number. An adding machine is coupled to the system at 12 gathering points so that as the parcels arrive, the operator calls up the branch number on the drum and, using this as the address of a particular store, updates that store with the new information.

Late each afternoon, the transportation manager,

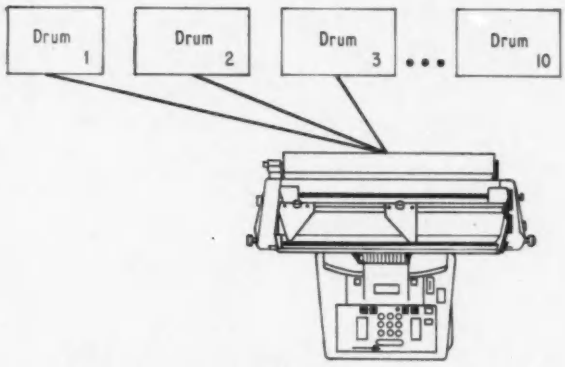


FIG. 4. In an electric adding machine-random access system, mechanical registers replace complex electronics.

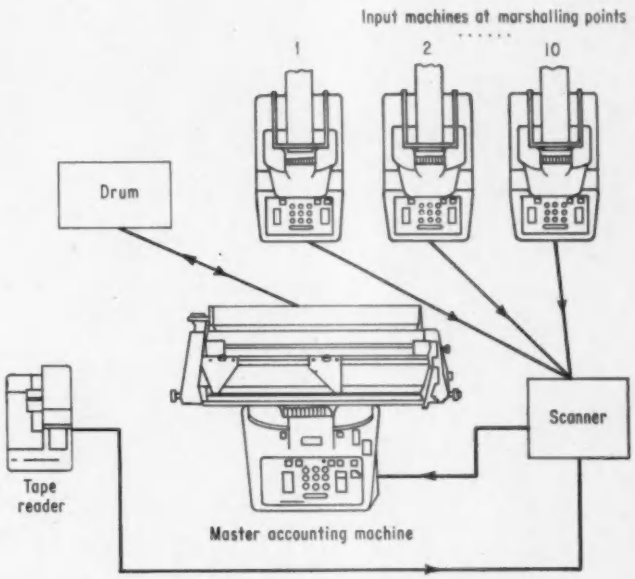


FIG. 5. Typical order picking system.

using a master adding machine with a punched tape reader, interrogates the drum to determine the total number of packages due for dispatch to each branch. To present the information to him in the most logical manner, the correct reading order of nonadd address code numbers is prepared on a prepunched tape. This is done in a way that the branch consignments appear in their correct geographical order to simplify assignment to trucks according to predetermined routes. The system (Figure 5) includes a scanning and interlock unit so that each gathering station gets in correct sequence for making entries on the drum. While this is being done, all the other stations are interlocked so that operators can enter addresses on their machines; but these will not print until each machine is connected to the data recording system. Readout by the master station resets registers at gathering stations for a new input.

3. Automatic averaging system for 10 inputs

An auxiliary stepping switch linked to the scanner selecting the incoming signals permits averaging over a range of 10 counts. As each reading is scanned and entered into the machine, the auxiliary stepping switch advances one position. The tenth step actuates the adding machine total solenoid. The average of the previous 10 readings is then printed out —by shifting the decimal point one place to the left—with an identifying symbol and the machine cleared for the next operation. The nonprint solenoid is energized during these 10 readings to insure that the only record that is printed out is the average of each 10 readings.

Another variation uses the subtotal or running total solenoid instead of the total solenoid. This permits limit testing to the average of a set of readings, so that corrective action is taken only after a number of samples have been measured and recorded.

4. Comparison unit for automatic limit testing

A simple limit tester can be made by adding a scanner and three sets of 10-position switches to an electric adding machine model that has a credit balance feature producing negative numbers as true values instead of complement figures. Figure 6 shows the layout of a simple $840 system with a 6-sec per test operating speed.

First the actual digitized quantity is fed into the machine and recorded in the register. With the nonprint solenoid energized, the scanner reads the high limit previously set on the first set of 10 position switches. This is read into the machine and subtracted from the digitized quantity. If it is within the higher limit, the credit balance contact indicates a negative quantity. The scanner next continues by rereading the high limit number and entering it into the machine and adding. This restores the original digitized value in the register.

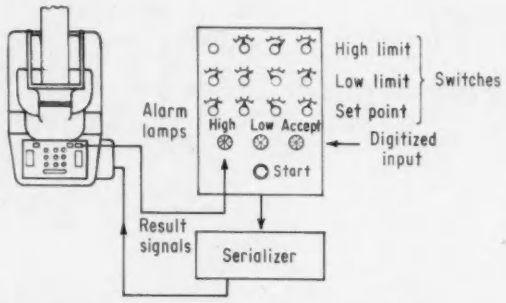


FIG. 6. Simple limit tester checks against high and low limits and prints out deviation from setpoint.

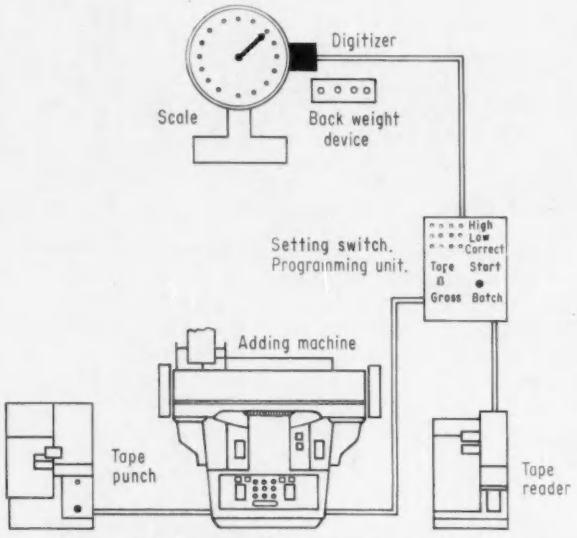


FIG. 7. Punched tape provides temporary memory for this 150-container automatic weighing system.

The lower limit is now read in and subtracted, and if the original reading is above the lower limit, the credit balance contact now shows a positive quantity. The original digitized value is restored in the register once again by refeeding the lower limit into the machine and adding. The next operation inserts the desired value into the machine which is subtracted from the original digitized quantity. The nonprint solenoid is now released and the difference total printed out as the deviation from desired value in red or black, according to whether above or below the setpoint. Closure of the credit balance contact outside the high or low limits operates suitable alarms.

An example of the system is shown in Figure 7 where equipment is attached to a digitized weighing scale with a special "back weight" device designed to handle a train of 150 containers which pass over the scale. They then remain in sequence, pass under a filling device, and travel back to the weighing station. The purpose of the weighing procedure is to determine the exact weight of the contents in each container and give immediate indications of containers whose filling lies outside high and low preset limits. Punched tape is used as a temporary information store, and the adding machine provides the cheap basic component of this simple, practical, automatic data processing system.

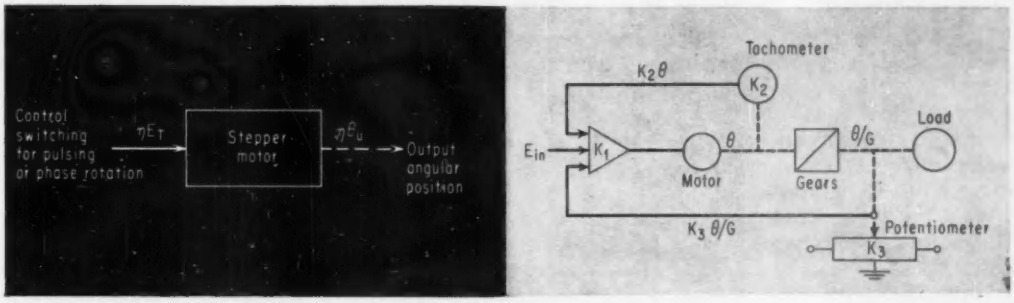
The first operation allocates a consecutive code number to each container. The preset back weight is then recorded and added to the digitized scale reading to print out the true tare weight. At the same time both the code number and the tare weight are punched on five-channel paper tape, and the completed tape is stored to await the return of that particular container series after filling. When the full containers arrive at the scale, a new back weight is set up and the appropriate punched tape is inserted in the reader. As each container passes over the scale and its code number is read from the punched tape, the true gross weight is printed out as derived from the new preset back weight and digitized scale reading. The tape now advances to read into the system the true tare weight. This is automatically subtracted to give the actual net weight of the contents of the container. Limit testing techniques (see heading number 3) are applied, and the container is automatically routed to one of three sidings, depending whether it is in limits, or over or underweight. Various programmings of the adding machine allow either all the information referred to above to be printed out or merely the basic essentials.

5. ADP system with tally marking

A simple ADP system using adding machine components was installed in a laundry for $1,062. Here a modified adding machine with electrical input is used with a remotely placed operator's input position. At the input position, pushbuttons labeled with a particular article or group, (sheets, blankets, collars) are operated as the incoming laundry is being unpacked. Each input to the adding machine enters the register of the machine and prints out in a special format on the tally roll denoting the quantity of articles, their code number, and the price per unit. Prewiring between the input keys and the adding machine solenoids allocates the correct article price to each article code. After unpacking, the operator remotely totals the entries to print on the tally roll the total number of articles and their value. The tally slip is removed and pasted into the customer's laundry book, thus performing both accounting and checking procedures simultaneously in one operation. Use of a double register machine allows the simultaneous transfer of this total to the second accumulating register to give a daily check of the number of articles handled and their total value.

Incremental Servos

Part I— Stepping vs Stepless Control



S. J. BAILEY, Vitro Corp. of America

THE GIST: The incremental servo, within its own limited frequency range, is slowly but surely becoming a strong contender for the position now occupied by the more conventional stepless servos. In this first part of a series written especially for Control Engineering, author Bailey leads off with a comparison of the characteristics of both stepping and stepless servos. These are summed up neatly in Table I which shows that, except for high frequency applications, the incremental servo is every bit as versatile as its stepless counterpart, the velocity servo. To further illustrate the flexibility of the stepper, Table II presents eight functional block diagrams. The author concludes this introduction with a review of the more important classifications of steppers. Part II will continue with a discussion of system design problems and methods used to solve them.

Incremental servos offer many of the advantages of closed-loop systems and minimize some of the troublesome or critical design problems.

The figure above compares a position servo with its incremental counterpart. Synthesis of the conventional system involves careful choice of several matched components and ultimate empirical adjustment of gain and stabilization to an optimum compatible with expected load variations. Even a packaged servo requires these final adjustments.

On the other hand, an incremental servo may be specified for an application by defining the load torque, nature and magnitude of the input, allowable positioning error, and response time. Usually the package may then be applied with a minimum of further adjustments.

The comparison of the figure is considered valid because a stepping motor may be viewed as the simplest form of incremental servo; i.e., for each input signal its output shaft assumes a new increment of angular position. A one-to-one correspondence of output shaft position to input signal results from the use of some kind of detenting. Physically and analytically this effect resembles the feedback of a conventional position servo.

It could be argued that a stepping motor is not a true position servo because it does not "measure" the position of its output shaft, feed back a signal proportional to this measurement, compare it to the input signal, and then apply the difference to torque the output shaft to its correct position. This argument would certainly stand up under technical scrutiny, yet it must be noted that if command information were available in small sign-sensitive "bits" to which the stepping motor could respond

with high incremental accuracy and stability, the motor would then perform the basic function of the position servo within the limits of its "frequency response" and incremental accuracy.

Frequency response here refers to the motor's ability to step at a rate compatible with the input pulse rate. This is essentially a "data sampling" problem and will be referred to later. Right now it would be well to compare the two kinds of servos to get a clearer picture of their characteristics.

Major differences

Generally the stepping motor is analogous to a velocity servo in that the incremental speed of its output shaft is directly proportional to its digital input rate, just as the speed of the velocity servo's output shaft is proportional to the amplitude of its analog input. Table I provides a concise comparison of these two servo types.

One outstanding physical distinction is that whereas the velocity servo gets its linearity through high loop gain (velocity feedback), the incremental device derives its linearity from a carefully designed mechanical and/or electrical detenting which results in an exact discrete shaft advancement for each element of stimulus.

Perhaps the most important functional distinction is the inherent stability of a stepping motor as compared with a stepless feedback device. This same stability may, however, become a problem under certain load conditions.

From an operational standpoint, a velocity servo performs as a true integrator since the position of its output shaft is proportional to the time integral of its input voltage. An incremental servo, however, is operationally a finite summing device in that its output shaft position is proportional to the sum of all its finite input pulses. Conditions under which the incremental servo may be viewed as an integrator, without analytical penalty, will be discussed in Part II of this series.

Another significant difference is that while rate feedback tends to linearize and stabilize the velocity servo, *feedback pulses* may be used to key the stepping motor output to its input in either a self-triggering or completed-step monitoring function. *Without* feedback, the stepping device is both linear and stable, provided the input pulse rate stays within the performance capabilities determined by the fundamental time constant. *With* feedback, the stepping device may be adjusted so as to be self-stepping for a continuous voltage input, until this voltage drops below some design threshold. Limitations of this technique are discussed in texts on sampled data theory. It is mentioned here simply to illustrate the versatility of the incremental servo.

Whether the detenting of the incremental servo is mechanical, electromagnetic, mechanical clutching, or electromechanical braking, it must be positive. Basically, the design prevents load fluctuations from developing a position error torque as happens in stepless servos. This feature is a definite advantage in systems with low data input rates and those which demand high "zero-frequency accuracy". But today's incremental servos cannot replace high frequency response, high load-variant systems.

Basic stepping contols

Table II shows a group of basic operational techniques which, in suitable combinations or iterations, serve as building blocks for larger systems.

The elementary building block (Row a) is, of course, the stepper motor which even without position feedback has the basic physical and analytical nature of a position servo when viewed for the interval of a single step.

Many systems operate with a data influx of a very low time-variant nature. Examples of such systems include celestial trackers, drone controls, some machine processes, and many chemical processes. Stepping motors make ideal integrators for these systems because of their basic simplicity and fine incremental accuracy. Response of these systems is such that the stepper motor transform (assuming a small step increment, e.g., 1 deg or less) may be written as 1/s (Row b).

Where the system involves computer controlled actuators (as in three-dimensional precision contouring) the bidirectional stepper may serve as a highly accurate finite (algebraic) summing device (Row c). But note the basic versatility of this device. For example, a designer may ignore the exact finite

WHY USE STEPPERS?

The following list covers advantages found in both open and closed-loop incremental servos:

1) When properly applied, the incremental servo offers all the desirable features of a feedback system without hunting or instability.

2) Careful fabrication can reduce error to a finite predesigned quantity with a relatively clean null and predictable threshold.

3) Proper selection of finite step components can save money; e.g., a suitable stepper may replace amplifier, servomotor, tachometer, gear train, and transducer.

4) Complex system synthesis becomes more straightforward; performance of elements and subsystems is easier to predict, and the interaction between system loops is easier to control.

5) Power consumption for intermittent operations can be reduced to zero during quiescent periods, a feature useful in the design of missile and space vehicle controls.

6) Use of an essentially digital system is far more compatible with advancing digital data techniques; both digital and analog outputs are available, though, as well as the discrete step mechanical output.

TABLE I—VELOCITY AND INCREMENTAL SERVOS COMPARED

CHARACTERISTICS	VELOCITY SERVO	INCREMENTAL SERVO
Nature of device	Displacement input, rate output	Pulse rate input, stepping rate output
Operational effect	Integration	Finite summation (may be analyzed as an integrator under certain conditions)
Angle or distance of output member travel	Time integral of analog input	Exactly determined by number of input pulses
Inputs	Analog voltage—other inputs through D/A converter	Uniform pulse train or random positive or negative pulses—analog signals through A/D converter
Velocity feedback	Output member rate	Not required—may be used for self-stepping or hold gating
Loop gain-linearity	Set high for high linearity	Stepping linearity does not require feedback
Stability (as position servo)	With position feedback loop, depends on rate damping (non-dissipative), dissipative damping, and/or lead networks	Not ordinarily a problem when operated open-cycle as a position control; when operated closed-cycle, stability is a function of step-to-signal frequency ratio
Error	With position feedback loop, depends on feedback transducer resolution and linearity, quadrature, noise, stability, etc.	Depends on accuracy of individual stepping mechanism within limits of designed stepping rate
Resolution	Governed mainly by feedback transducer resolution assuming high loop gain	Depends on built-in step size
Response time	50 millisec, time to achieve maximum error correcting rate in typical instrument servo	10-30 millisec, time to complete one step (typical); total time depends on error size
Frequency bands	Zero to high frequency response device	Relatively low frequency response device
Torque	Obtained through reduction gear train	Usually available at output shaft of stepping device
Load variation	Develops driving torque through error feedback	Has no influence on motor drive under proper detent conditions
Digital programming	May be adapted with D/A input device and data encoder on output shaft	May be commanded directly by computer or tape pulse train
Two-mode operation (slewing or inching)	Readily adapted	Readily adapted—many steppers will slew as well as step
Quiescent power	Must be fully energized while awaiting command	Zero power drain while awaiting command
Life—reliability	Dependent on amplifier, motor tachometer, feedback potentiometer, and gear train	Dependent on pawl, ratchet, or other mechanical and electrical elements of a single motor
Cost	Dependent on cost of amplifier, motor, tachometer, feedback transducer, and gear train	Dependent on cost of single torque unit, with or without control trigger

summing, increase the stepping rate, install a high reduction gear, and use a binary encoder wheel to detect the output shaft position for comparison with the computed or taped command.

Used as a velocity servo (Row d), the stepper responds linearly to a pulse rate input, within the limits of its stepping speed range. This application points up the compatibility of incremental servos with digital computing and control techniques.

As a conventional positional servo with potentiometer feedback and a polarity-sensitive comparator having pulse gating circuitry (Row e), the average stepper becomes quite compatible with analog instruments and programming controls of moderate frequency response.

Quantizing analog data is a very important system function because physical phenomena occur in analog form. Row f shows how a stepping device may be used to quantize or "count" analog data in equal amplitude segments. Note the irregularity of the time base.

The diagram in Row g shows a simplified arrangement for data sampling. Here the time base is regular. Sampling pulses are generated at equal time intervals, and the outputs correspond to the function value at the discrete sampling angle. Somewhat analogous to stepless two-speed data transmission is the two-mode control shown in Row h. Here the stepper motor performs either the "slewing" or "inching" function, depending on the size of the error. A phase-pulsed synchronous stepper motor can be designed to operate on demand as a conventional motor by abruptly increasing pulsing rate considerably beyond normal stepping speed. Digital circuit logic is needed to sense error magnitude.

Classifying steppers

Depending on the criteria chosen, steppers can be classified in many ways. The following discusses classifications based on seven important criteria.

Basic Type—Broadly speaking, steppers fall into either of two basic classes: phase-pulsed synchronous and solenoid-ratchet. The first includes multiple phase switched rotating machines which develop counterbalancing torque to cause stepping. The term "phase-pulsed synchronous" refers to phase synchronous motors which have special rotor and pole piece arrangements and which step in accordance with the progressive switching of two or more phases. (Actually the two-phase devices require a permanent magnet field as part of their stator array.) Steppers in the second class include both rotary and rectlinear actuating devices with ratchet or escapement detenting. In this type electromagnetic actuation of a solenoid core or armature produces the shaft rotation.

Step Starting and Stopping Methods—Perhaps a more revealing classification of steppers would be according to these two basic characteristics: starting and stopping methods. According to the first, steppers may be classed as rotary, rectilinear, and coupling solenoids; relay armature; two-phase-pulsed synchronous with permanent magnet; three (or more) phase-pulsed synchronous; and pulsed synchronous with brake. Stopping methods include: pawl and ratchet, escapement, spring clutch, magnetic clutch, reverse balancing torque, and no-current holding torque.

Rotation—Steppers may be further classed as unidirectional and bidirectional. Bidirectional stepping usually involves duplicate actuators. In solenoid-ratchet devices, for example, two solenoids with opposite rotational sense are installed. In two-phase-pulsed synchronous devices, two counterrotating units are mounted on a single shaft. Reversing a device with three or more phases requires simply a change in the order of phase excitation.

Inputs and Input Acceptance—Another useful classification of steppers is by input types. Commutation or simple switching is the usual means for handling input signals. Auxiliary input elements or circuits frequently used include: transistor triggers; polarity sensitive analog comparators with pulse-gating facilities; ring computers; thyratron triggers; relays, transformers, magnetic amplifiers, vacuum tube triggers, etc. With respect to input acceptance, steppers generally fall into two classes: those which are energized by successive switching of power into the windings and those actuated by pulses having critical definition as to rise time, duration, and amplitude.

Output Torque—If classified with respect to output torque, steppers cover a wide range of types. At one extreme are the precision instrument torque clocks and at the other end, machine tool power drives.

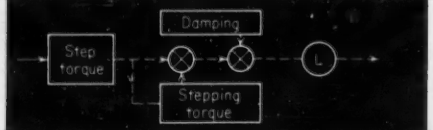
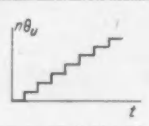
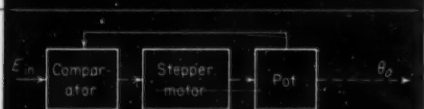
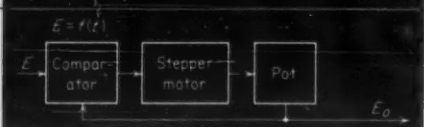
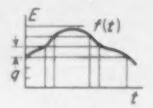
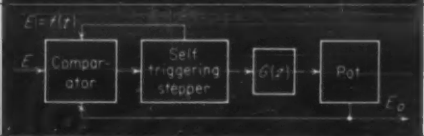
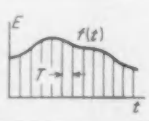
As a precision torque clock, a stepper might have an individual step accuracy within 3 min of arc. Its stepping function would yield increments of angular motion of practical size (from a fraction of a degree) at available rates of from 5 to 100 reliable steps per sec. Its output torque might range from 1 oz-in. to 50 oz-in., depending on the size and model. Used as a clock, it could be set in motion by a single input pulse and would continue to step at a reasonably fixed rate either independently or for a fixed time.

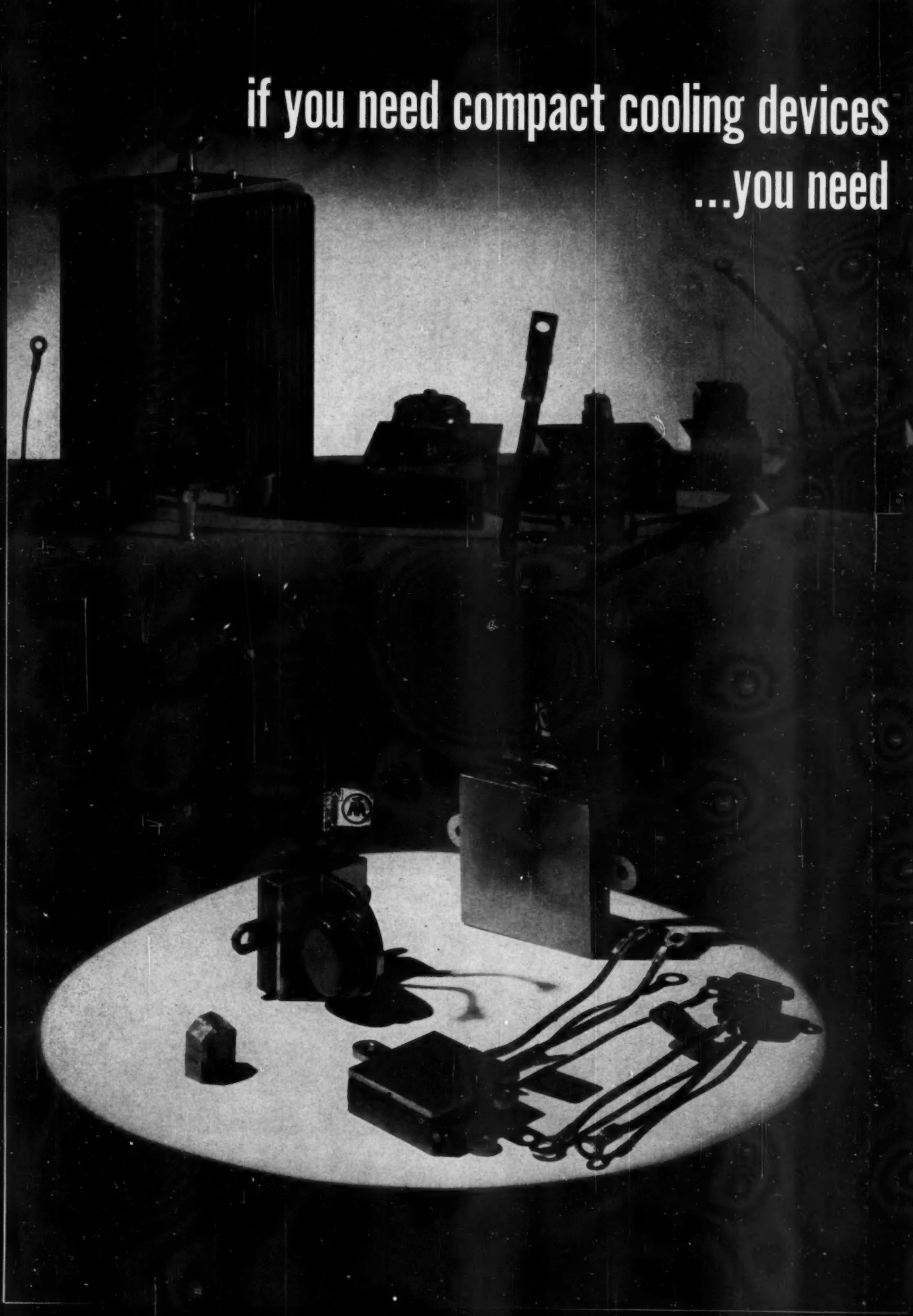
At the other end of the torque range, a stepping control may be visualized, for example, in terms of a tape-controlled milling machine for three-D contouring, with torque in excess of 2,000 lb-in.

Design problems next

This concise introduction to the subject of incremental servos leads to the conclusion that stepping devices can be designed for almost any precision automatic control application and that the chief limiting factor would probably be frequency response. In the next part of this series, the author will describe some of the methods used in designing incremental servos, review the load matching problem, and discuss in some detail the analytical nature of these devices.

TABLE II—BASIC STEPPER FUNCTIONS

DESIGNATION	BLOCK DIAGRAM	CONTROL FUNCTION	EQUATIONS	EXPLANATORY NOTES
a) Elementary building block		During the interval of a single step, acts as a position servo, yet has no external position feedback loop	$\frac{\theta_o(s)}{E(s)} = \frac{K}{s\left[Js^2 + (f+f_d)\,s + K_s\right]}$	K = motor rad/volt K_s = stopping torque, gm-cm/rad f_d = adjusted clamping constant for load L $E(s)$ = disturbing voltage J = moment of inertia motor plus load
b) Integrator		In a very low frequency response system, operates as an integrator	$\theta_o(s) = KE(s) \times \frac{1}{s}$	The time-variant nature of the system data is such that no significant loss is suffered by regarding the stepper as a continuous function device
c) Finite summing device		Accounts accurately for each input pulse--is a staircase generator or reversible counter	$\theta_o(s) = \frac{\theta_u e^{-t_c s}}{3} \sum e^{-(n-1)Ts}$ $n = 1, 2, 3, \cdots, n$	 θ_u = unit step t_c = delay per step T = $t_{on} + t_{off}$ t_{on} = required trigger on-time t_{off} = required trigger off-time
d) Velocity servo		Stepping rate proportional to input pulse repetition rate	$\frac{\Delta\theta_o}{\Delta t} = K_v \frac{1}{T}$ (Steady state equation)	In the command computer the analog function is converted to proportional pulse rate (A/D) K_v = proportionality constant $1/T$ = sampling (stepping) rate
e) Position servo		Analogous to conventional position servo with feedback loop	$\theta_o = n\theta_u = nK_p E_T = E_{in} = E_R$ (Static equation)	θ_u = unit step value n = number of steps K_p = proportionality constant E_T = trigger voltage E_R = nontriggering voltage remainder E_{in} = input voltage
f) Data quantizing		Stepper is responsive to unit changes (q=quantizing width) of input function. Note: Input function has very low rate of change compared with stepper speed of response	$E_o(s) = \frac{qe^{-t_c s}}{s}\left[1 + e^{-t_1 s} + e^{-t_2 s} + e^{-t_3 s} \cdots\right]$ $0 < t_1 < t_2 < t_3 \cdots\cdots$	 K_r = proportionality constant $\theta_u = K_r q$ = unit angle q = quantizing width $e^{-t_c s}$ = step time delay (transportation lag)
g) Data sampling		Self-triggering stepper is polarity sensitive to error signal. Samples input at equal intervals regardless of amplitude change (incremental sampling servo or impulse modulated staircase generator)	$E_o(z) = \frac{E_{nT}}{(1-z)(1-z)} \times \frac{G(z)}{1+G(z)}$	 E_{nT} = value of $f(t)$ at nT $z = e^{-Ts}$ $G(z)$ = Dynamics of stepper and networks in forward channel (z-transform) T = sampling period, includes t_c
h) Slewing and inching servo		Control automatically puts stepper into inching mode when error becomes small	Slewing: Similar to a above Inching: Similar to e and f above	EVL = error value logic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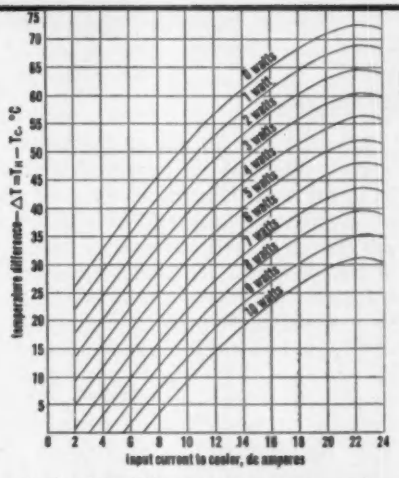

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CIRCLE 129 ON READER SERVICE CARD

How They Tested the First Nuclear Rocket Engine

Testing a new family of solid core nuclear reactors designed for rocket propulsion was a tricky job because testers had no experience or background with such a reactor. Here in pictures and diagrams is the measurement and control system designed for this pioneering test. Analog computer techniques made real-time displays possible.

Kiwi-A, the U.S.'s first nuclear rocket engine, posed some formidable instrumentation problems during its initial tests. Because the reactor was unshielded, no instrumentation could be repaired after the unit was started up and run even at low power. Because of the design of the unit, it was believed that an emergency shutdown (or scram) at a high power level would likely end the useful life of the engine so that instrumentation and control had to be reliable enough to prevent an unnecessary scram. The number of measuring devices and transducers that could be put inside the critical assembly was limited since the designers of high power density reactor cores objected to the placement of many nonuclear devices in the core (it cuts down power generation). And the design of the high-pressure-proof shell that contains the reactor was not conducive to bringing out a large bundle of instrumentation wires.

Named after a flightless Australian bird, the Kiwi-A engine was never intended to fly, even in rudimentary tests. That simplified the instrumentation and control problem somewhat. For example, there was no requirement to miniaturize equipment, and the test could rely on wire transmission of data instead of radio telemetry.

The system that was finally selected for measurement and control by Los Alamos Scientific Laboratory's instrument contractor Edgerton, Germeshausen & Grier, was pure analog hardwire telemetry, using analog computer techniques for automatic control and for closing servoloops. Strip chart recorders and meters were the primary recorders and data displays. The analog system lends itself admirably to the large number of real-time displays that were asked for during the test because testers had no background or previous experience with such an engine.

Some other advantages of an analog approach in this test:

1) Accuracy and frequency response required were compatible with analog systems. Quantitative channels had an accuracy of plus or minus 1 percent and a frequency response of 40 cps.

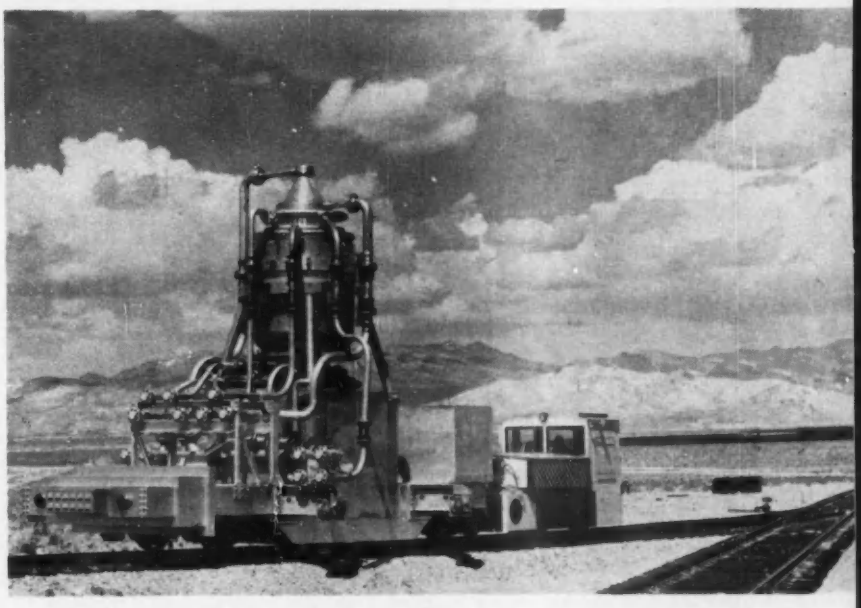
2) Requirements for closed-loop servo control channels were more readily met with analog systems than with digital systems.

3) With the distances involved, buried cables represented a more economical and reliable transmission scheme than did radio telemetry.

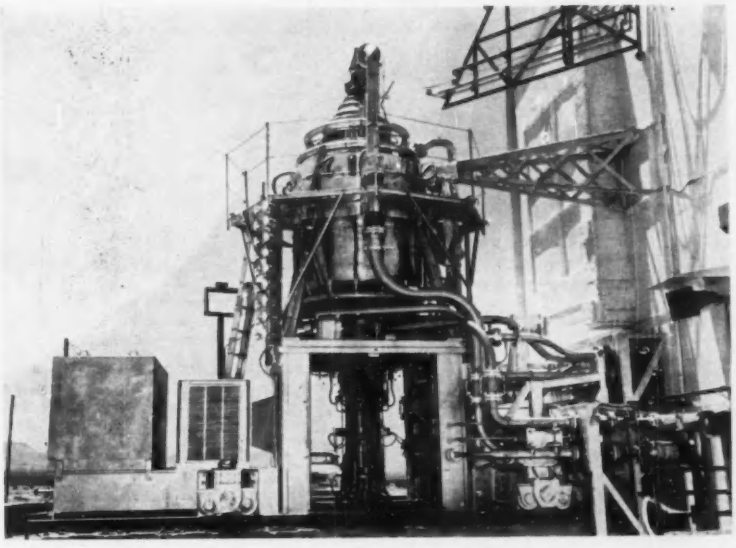
Over 800 signal and command channels were telemetered by wire over the two miles separating the test cell from the control building. Automatic control was of particular concern to the reactor control group, particularly during rapid startup, because the temperature coefficient of reactivity (how the multiplication of neutrons would proceed with a change in temperature) was unknown. A complex analog computer received information on temperature, power level, and propellant flow rate, compared these with designed conditions, and then transmitted command instructions to the power plant controls.

Data processing for the Kiwi-A tests was relatively simple compared to testing of a missile, for example. For one thing, testers did not have multiple tests day after day. For another, much of the instrumentation was for disaster only—the data from these devices to be reduced only in case of a malfunction. Semimanual techniques could be used in the Kiwi-A test because the amount of data to be processed was limited.

The first test of a solid core reactor operation at temperatures and power densities and with propellants applicable to nuclear rocket propulsion was an unqualified success. With the data and experience gathered in this test, the Atomic Energy Commission has been able to refine its nuclear rocket engine development. Just recently, full power tests were successfully completed on Kiwi A Prime, an advanced version of Kiwi-A. Testing Kiwi A3, an even more advanced design, is to be started soon.

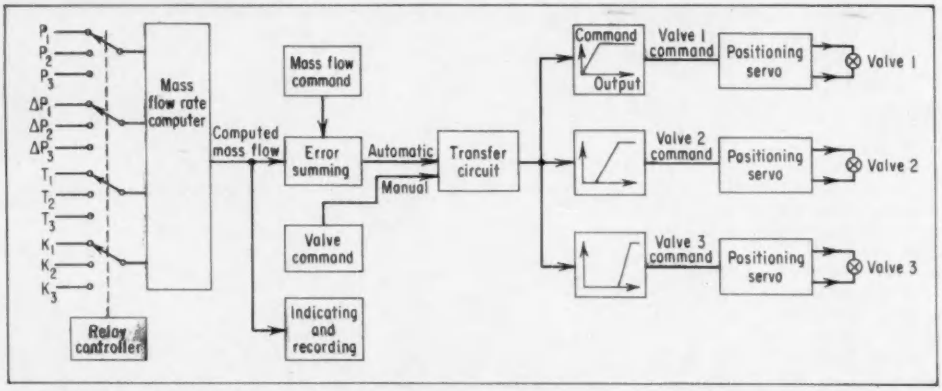


Kiwi-A, nonflying nuclear rocket engine, was mounted on a special railroad car so it could be withdrawn remotely from the test cell even when it was radioactive. The reactor has a solid core in which uranium is imbedded in a refractory material to form a fuel plate. The fuel plates are arranged alternately with free passages so that the propellant or coolant (hydrogen gas) can be forced through them, heated as in a heat exchanger, and then converted to thrust by means of a conventional rocket nozzle.



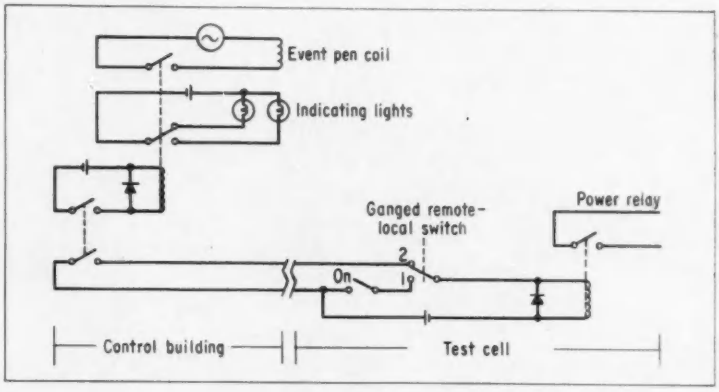
In the test cell the unshielded nuclear rocket engine was positioned above a slightly shielded working space which contained control rod actuators, wiring terminations, and some transducers. Control equipment for local operation, neutron detectors, and some electronics were also installed in the test cell.

Test was run from this operating control console. Instrumentation is divided into two groups: that which must contain a high degree of quantitative fidelity for diagnostic and control requirements, and that which is binary for on-off commands.

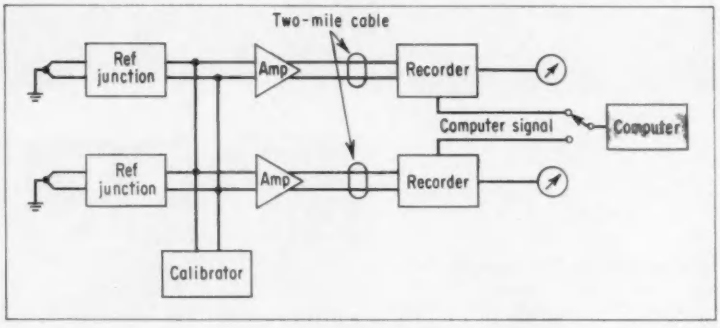


Control circuitry is typified by the flow control system which provides manual or automatic regulation of the hydrogen propellant. An upstream venturi measures pressure, temperature, and throat differential. Because of the range of flows contemplated, three venturis—a small, medium, and large—were installed, to be used one at a time. Next a relay controller automatically switched to the appropriate input variables for the venturi-valve combination in use at the time. Switching took place whenever the ratio of venturi differential pressure to upstream pressure exceeded a given maximum value. Mass flow rate was computed by analog techniques and compared at a summing junction to the commanded mass flow rate. The difference, or error, was applied to the three valve positioning servos. As the valve position command increased from zero, for example, the smallest flow valve opened proportionately to a limit where it held. At this limit the medium valve opened until it, too, reached full stroke and held. Then the large valve opened proportionately. The reverse occurred for shutdown.

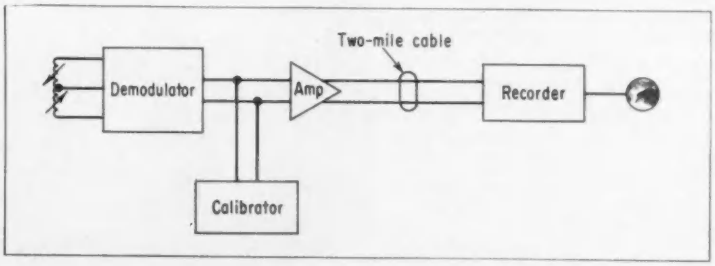
On-off command channel. Only enough power to operate a pilot relay was transmitted in the long lines. All relays were low voltage dc units, equipped with diodes or similar suppressors. Switching a command "on" actuated an on-off recorder pen coil and an indicating light in the control building as well as the power relay that performed the function. Ganged switching in the test cell permitted local control of the command circuit.

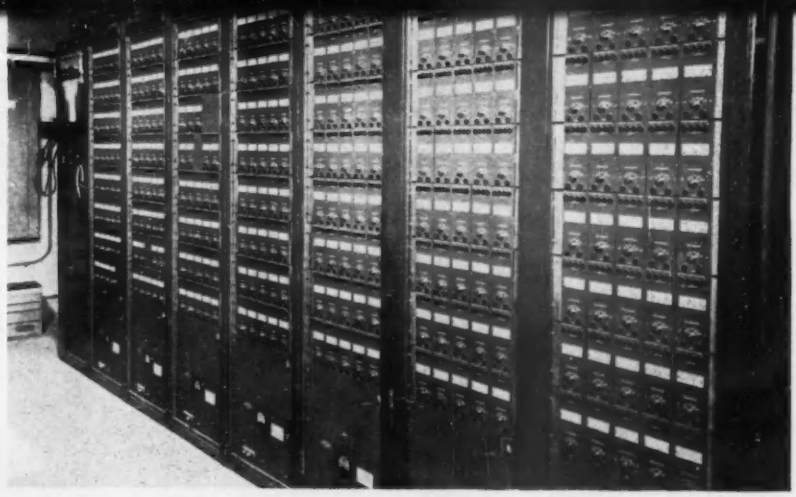


Typical temperature measurement. Each measurement was backed up by a second one made by a different thermocouple. Thermocouple wires led to an electrically heated reference junction and after amplification up to a recorder in the control building. Each channel also had an indicating meter. An operator watching these meters selected one of the two signals to feed into an analog computer making real-time calculations such as mass flow rate of propellant.

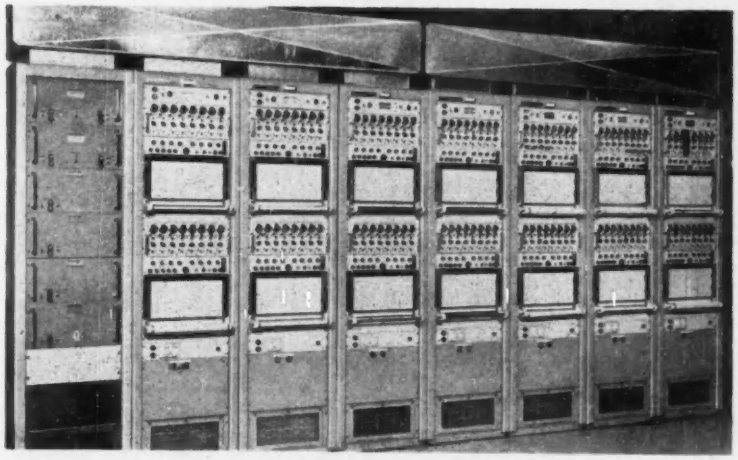


Typical pressure channel. Ac excited pressure transducers were generally used and these signals were demodulated before being fed into the dc instrumentation system. Transducer outputs were modified to present approximately 10-mv full scale dc signals to preamplifiers. Long line transmissions were accomplished at a 10-volt level in balanced dc.



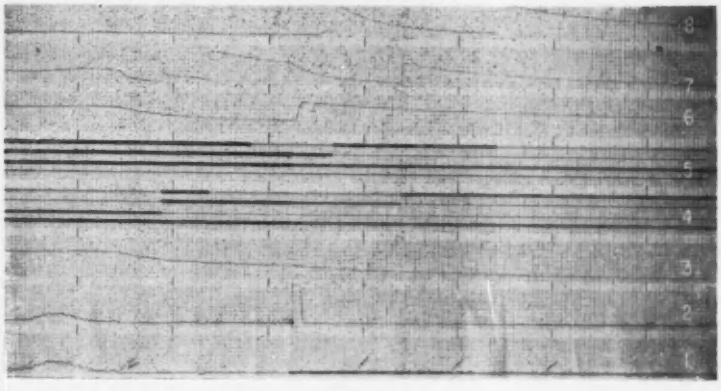


Signals from pressure transducers and thermocouples were amplified by these chopper preamplifiers in a distribution building located close to the test cell. With vacuum tube circuitry the amplifier has a 400-cycle, double pole, double throw mechanical chopper for both its differential input and its balanced output. Other preamplifier characteristics: high input impedance, low output impedance, linearity of plus or minus 0.1 percent, gain stability of 0.1 percent, zero offset of less than plus or minus 10 microvolts equivalent input, common mode rejection of 100,000 to 1 at 60 cycles, and low noise and ripple. Balanced signal lines were used to minimize crosstalk and pickup.

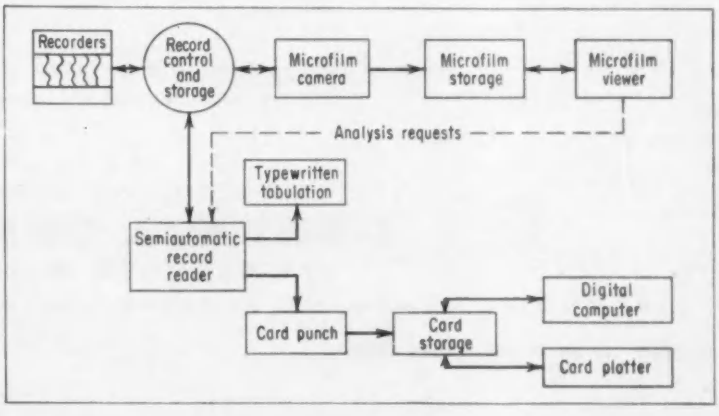


Multichannel strip chart recorder was a heat writing unit, packaged 16 channels per rack. Each recording channel has two amplifiers built into the rack: so-called control and power amplifiers. A vacuum tube device, the former is the signal conditioner—its input is balanced and its output is single-ended—and performed all gain controls and zero suppressions. Its output, single-ended, provided input information to the analog computer, oscilloscopes, and other high impedance devices. The transistorized power amplifier amplified the signal sufficiently to drive the high torque galvanometers. These recorded the signals, provided isolation sources of signals suitable for driving low impedance displays like meters and high impedance elements like computer operational amplifiers, and provided balanced termination for the long lines.

Typical record carried eight analog channels on a 16-in. paper width. Any analog galvanometer, however, could be replaced with a four-stylus on-off assembly (channels 4 and 5 at right) to record both the analog signal and related on-off indications. With this arrangement, flow rate and control valve limit indications, for example, could be recorded adjacent to each other. Trace also carried a reference line to compensate for possible paper shift and a digital time code placed on it by a timing pen driven by a special time code generator.



Data reduction was semiautomatic. Strip chart records were reduced to microfilm because it was easier to scan them this way than to read the full sized records. If a reading was desired, a request was made and that strip chart trace was converted to punched cards or typewritten output in a semiautomatic reader. Cards which had been linearized and scaled in the reading process served as input to a card plotter or a computer.



New Random Access Memory Package...

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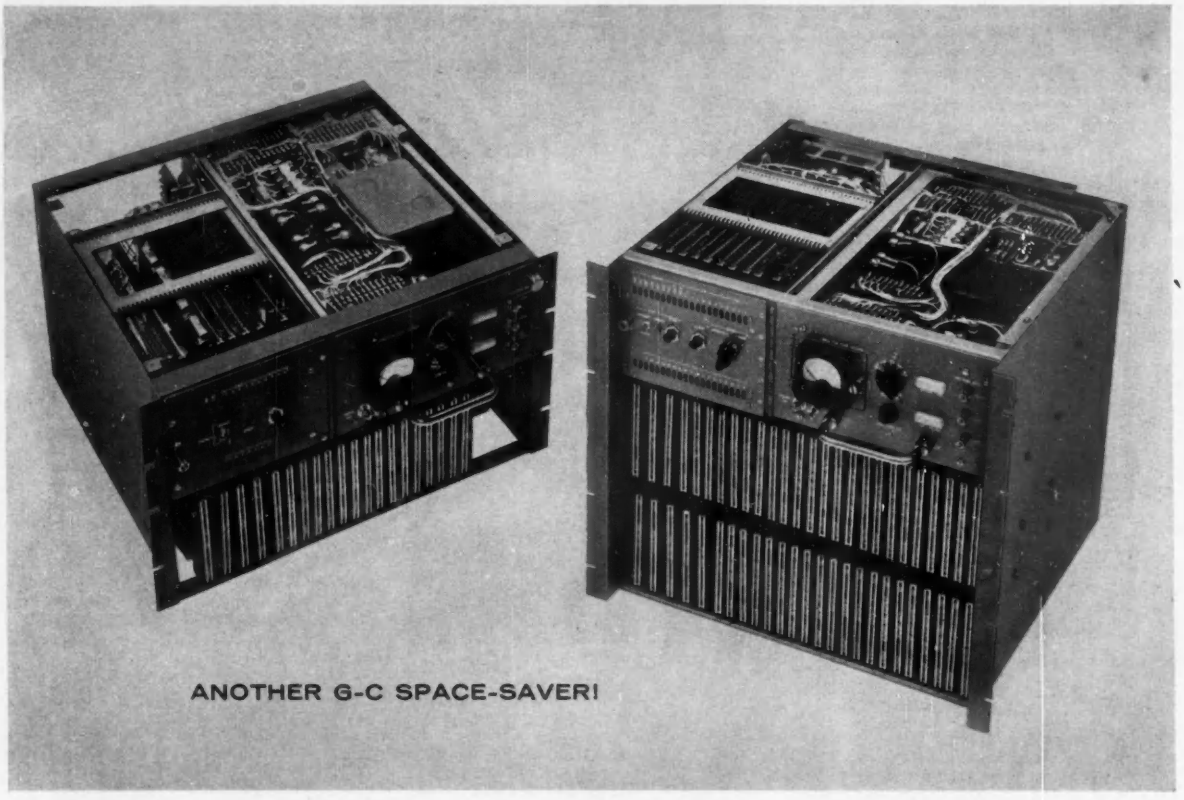

GENERAL CERAMICS, continuing its leadership in the memory packaging field, has made available double and triple bay random access memories with up to 4096 characters x 32 bits per character at cycle times up to 6 micro-seconds. Now you can get design economy since the basic G-C package requires only 18.75" of standard rack space—a reduction of up to 80% over typical units requiring a full six feet.

General Ceramics offers space-saving random access memory designs with varying number of characters, word lengths and logic.

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APPLIED LOGIC DEPARTMENT

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TECHNICAL CERAMICS, FERRITE AND MEMORY PRODUCTS

Simple Analogs for Useful Nonlinearities

A simple compensated varistor circuit is now available in a plug-in package that permits accurate synthesis of a whole class of useful nonlinearities. Here are several circuits based on its use.

L. D. KOVACH and W. COMLEY
El Segundo Div., Douglas Aircraft Co.

In the problems of synthesis it is often desired to introduce predetermined nonlinearities into the control system in order to achieve a desired result. Among the infinite number of possible functions, there is one class that is particularly useful. This is the class $y_n = x^n$. These functions are plotted in the unit square $0 \leqq x \leqq 1$, $0 \leqq y \leqq 1$ for various $n > 0$ in Figure 1. If $n = 1$, $y_1 = x$ is the straight line OB. If $n > 1$, the curves all lie below OB; and if $n < 1$, the curves lie above OB.

The Quadratron* is a versatile nonlinear element that can be used to synthesize the nonlinear y_n functions with high precision. It is a solid state device which is capable of squaring a voltage with an error less than 0.2 percent of full scale (plus or minus 100 volts peak to peak). Besides varistors which perform the squaring operation, the Quadratron package contains thermistors for temperature variation correction and resistors for making the unit compatible with commercial operational amplifiers.

Quadratrons have a wide dynamic range, and their passive character makes them extremely reliable. They are available in the two forms marked **P** and **C** in the figures. Their simplicity and low cost makes them unusually attractive as universal function generators of a variety of functions.

The ability to produce the class of functions y_n economically is important in achieving certain desired characteristics. If a nonlinear control action is introduced with $n > 1$, it will be sluggish in the beginning and rapid at a later stage. If $n < 1$, then the action will rise rapidly near $x = 0$ and level off later. Figure 2 shows Quadratron circuits for some of the y_n functions. The circuit of Figure 3 produces any power of input between $\frac{1}{2}$ and 2. Figures 4 and 5 are other useful functions.

To demonstrate how it is possible to achieve a certain desirable nonlinear behavior in a control system, it is necessary to consider the sources of these nonlinearities. There is a variety of effects which may cause nonlinear behavior in a dynamic system. One common nonlinear term is the result of the presence of an element in the system whose response is dependent on the amplitude of a dependent variable. For example, it is possible for the pitching moment of an airplane to vary with angle of attack in a nonlinear manner. This would cause a nonlinear term $C_m(\alpha)$ to appear in the equation of motion in place of the usual linear term C_{m_α}. In one typical airplane the variation of pitching moment with angle of attack is

$$C_m(\alpha) = -1.2\alpha - 4.0\alpha^2 - 90\alpha^3 \qquad (1)$$

If α is represented by a voltage, Figure 6 shows the circuit needed to generate $C_m(\alpha)$.

Second order linear differential equations often have variable coefficients. These equations are commonly written in the familiar form

$$\ddot{x} + 2\zeta\omega_n\dot{x} + \omega^2_n x = H(t) \qquad (2)$$

where ζ is the damping ratio and ω_n is the natural undamped frequency. Typical graphs of ω^2_n and $2\zeta\omega_n$ plotted against x are shown in Figure 7A and 7B. The circuit which represented these functions and also solves Equation 2 is shown in Figure 8.

A large class of second order systems capable of self-

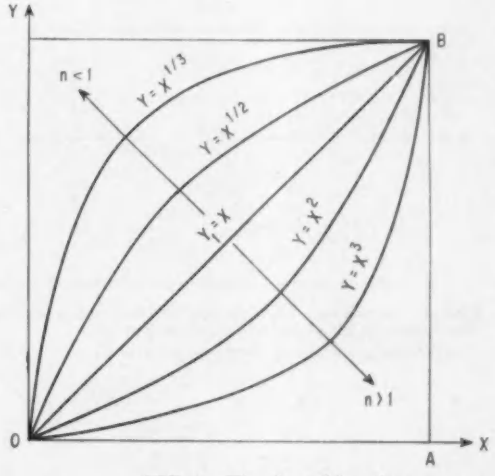


FIG. 1. The class of functions $y_n = x^n$.

* Douglas Aircraft Co., El Segundo, Calif.

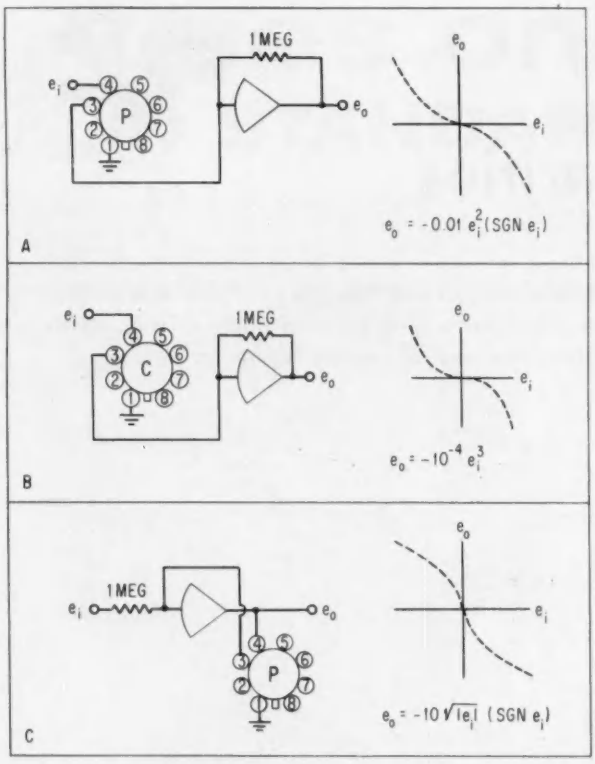


FIG. 2. A—Circuit for obtaining the function $y = x^2 \operatorname{sgn} x$; B—Circuit for obtaining the function $y = x^3$; C—Circuit for obtaining the function $y = \sqrt{x}$.

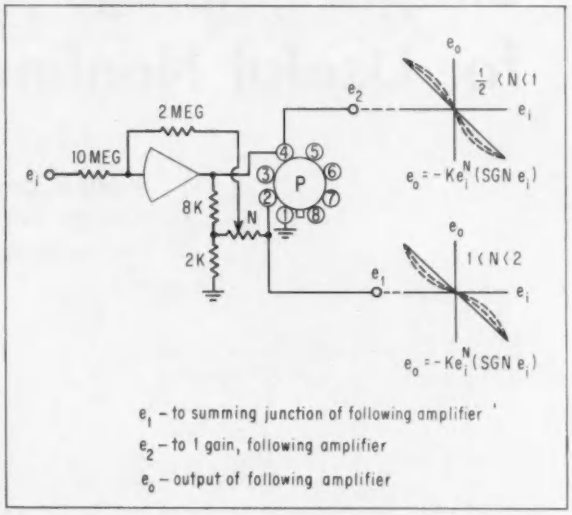


FIG. 3. Obtaining arbitrary exponents with the Quadratron.

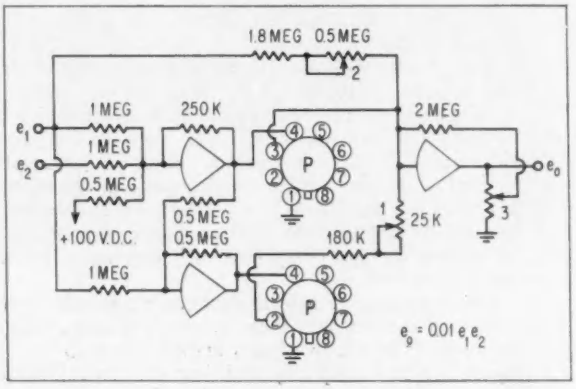
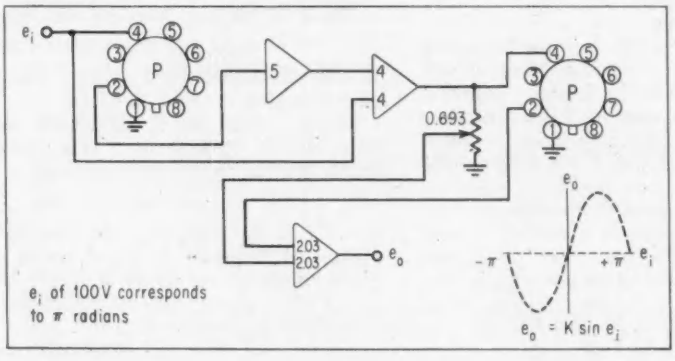


FIG. 4. A Quadratron multiplier.

FIG. 5.
A sine resolver
with Quadratrons.



sustained oscillations can be described by Van der Pol's equation. If the damping term has the form

$$f(y, \dot{y}) = -(C\dot{y} - D\dot{y}^3) \tag{3}$$

it becomes Rayleigh's equation

$$\ddot{y} - (C\dot{y} - D\dot{y}^3) + \omega^2 y = 0 \tag{4}$$

A transformation of variables,

$$t_1 = \omega_n t$$
$$x = \frac{3\omega_n^2 D}{C} y \tag{5}$$
$$\mu = \frac{C}{\omega_n}$$

puts the Rayleigh equation into the canonical form

$$\frac{d^2x}{dt_1^2} - \mu\left[\frac{dx}{dt_1} - \frac{1}{3}\frac{dx^3}{dt_1}\right] + x = 0 \tag{6}$$

This equation can be solved by the circuit of Figure 9 by inserting different values of μ.

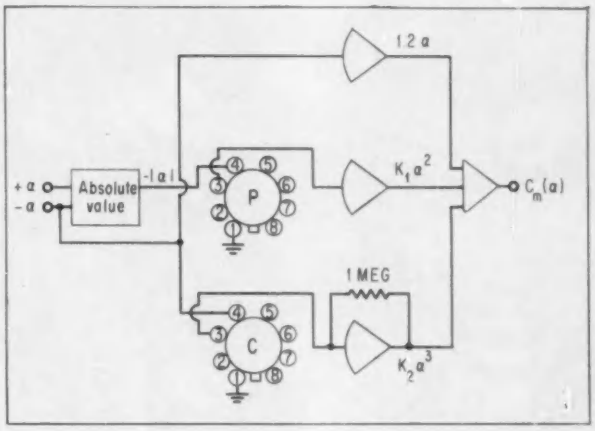


FIG. 6. Circuit for generating $C_m(\alpha)$, see text

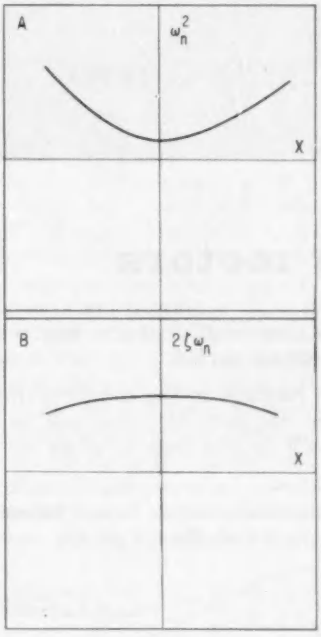


FIG. 7. A—Graph of ω_n^2 vs x in Equation 2; B—Graph of $2\zeta\omega_n$ vs x in Equation 2.

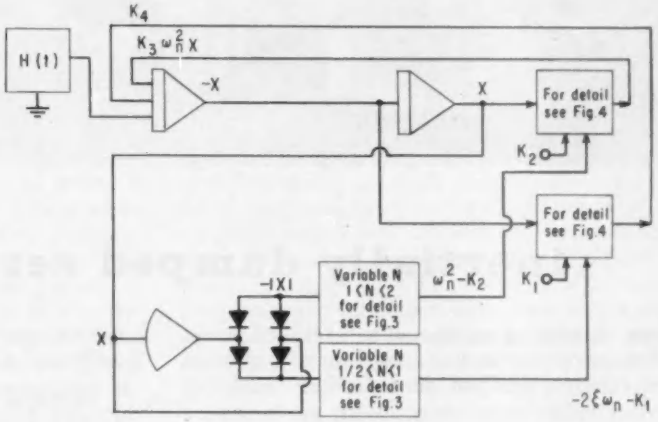


FIG. 8. Wiring diagram for solving Equation 2.

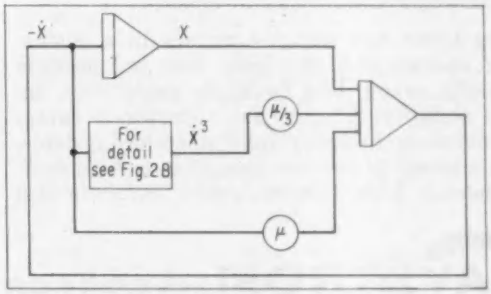


FIG. 9. Wiring diagram for solving Rayleigh's equation.

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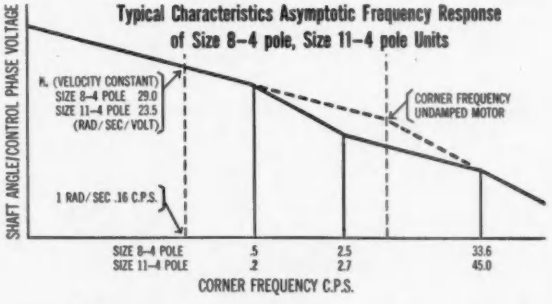

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CIRCLE 138 ON READER SERVICE CARD

Selecting Amplifiers for High Performance Servovalves

GIST: The hydraulic servovalve powered by a fast response dc torque motor is one of the best-performing components to become available to the control engineer. But its operation in a system depends to a large extent on the company it keeps. The servoamplifier, particularly, must be of special design if the response and accuracy of the valve are to be fully realized. This article discusses the bandwidth requirements for a compatible amplifier and describes one transistorized circuit that has been specifically engineered for servovalve applications.

RAYMOND E. CLAFFIN, JR.
Servocontrol Div. of The Oilgear Co.

The high performance characteristics of an electrohydraulic servovalve cannot be realized unless it is driven from a compatible amplifier. To achieve the necessary compatibility, the control engineer must carefully set his design objectives on the basis of response, bandwidth, type of system (dc or ac carrier), and frequency. The question of response is settled quite readily since a fast response valve clearly calls for a fast response amplifier. And once the decision in favor of a fast response amplifier is made, the problem of bandwidth can be evaluated.

The transient or step response of a control system is a function of the bandwidth of that system, since a sharp discontinuity of waveform (such as a step function) involves many high frequency components. For a pulse-modulated carrier frequency signal, the pulse response for the case of zero to moderate overshoot may be written as

$$T_R = \frac{0.70 \text{ to } 0.90}{B} \qquad (1)$$

where T_R equals the time (microsec) it takes for the leading edge of a pulse to rise from 10 to 90 percent of its maximum height. B is the system bandwidth (cps) measured between the lowest and highest frequencies where the response is 0.707 or more times the carrier-frequency response. Thus the greater the bandwidth, the shorter the rise time and the better the response for a step function input.

Wide bandwidth and fast response characteristics are readily obtained in dc amplifiers. But ac systems are preferred in many industrial and military quarters for reasons including reduced arcing across contacts, freedom from drift, and the availability of inductive and capacitive transducers. Wide bandwidth and fast response are easily provided in ac amplifiers too, if high frequency systems are acceptable. However in the majority of applications, generation of high frequency carriers entails additional equipment and introduces phase shift and capacitive pickup problems. For these reasons, 60 or 400 cycles are the commonly used carrier frequencies. Thus the problem here is the provision of fast

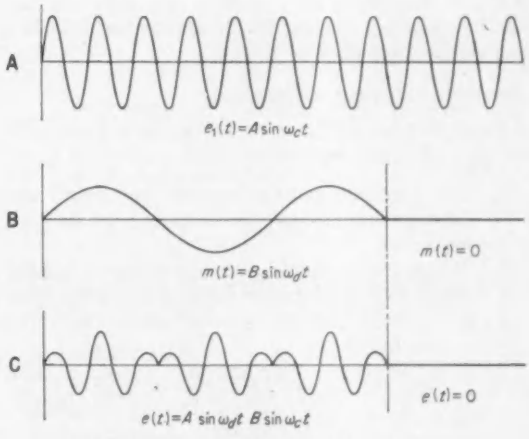


FIG. 1. Waveforms relating to (A) carrier excitation voltage, (B) mechanical displacement signal, and (C) modulated voltage output.

response and wide bandwidth amplification for modulating signals superimposed on a 60 or 400-cycle carrier.

Carrier modulation

Amplitude modulation of voltage wave $e(t)$ of carrier frequency ω_c (rad per sec) by a signal $m(t)$ may be described mathematically as

$$e(t) = m(t) \sin \omega_c t \quad (2)$$

where

$$m(t) = \sin \omega_d t \quad (3)$$

and ω_d is the frequency of the modulating signal. In a typical case the input signal may be generated by the mechanical displacement of a carrier-excited transducer such as a potentiometer. The input signal $m(t)$ then consists of the sinusoidal displacement of the brush of the potentiometer. From Equations 2 and 3 the expression for the output waveform becomes

$$e(t) = A \sin \omega_c t B \sin \omega_d t \quad (4)$$

where A and B represent the peak amplitudes of the modulating and the carrier frequency signals. As shown in Figure 1 the output voltage is zero when $m(t) = 0$, giving rise to the designation "suppressed carrier modulation". The phase reversal of the carrier at the crossover or zero points of $B \sin \omega_d t$ is also shown.

By manipulation of trigonometric identities, Equation 4 becomes

$$e(t) = AB[\tfrac{1}{2} \cos (\omega_c - \omega_d)t - \tfrac{1}{2} \cos (\omega_c + \omega_d)t] \quad (5)$$

or

$$e(t) = AB[\tfrac{1}{2} \cos 2(f_c - f_d)t - \tfrac{1}{2} \cos 2(f_c + f_d)t] \quad (6)$$

Thus the information of the modulating signal $m(t)$ is carried by an upper $(f_c + f_d)$ plus a lower $(f_c - f_d)$ sideband frequency, where f_c and f_d are in cps. If the modulating signal were 1 cps and the carrier 60 cps, the upper and lower sideband frequencies would be 61 and 59 cps. And if the modulating signal were 59 cps, the sideband frequencies would be 1 and 119 cps. Thus for a carrier amplifier to pass the information contained by a modulating signal of frequency, only slightly less than the carrier frequency, a bandwidth of approximately twice the carrier frequency is required.

Amplifier design objectives

From this brief discussion the following amplifier design objectives may be established:

1. The amplifier must accept ac suppressed carrier-type signals of the required phase and frequency.
2. The amplifier should pass, in as linear a fashion as possible, modulation frequencies in the spectrum from zero to approximately twice the carrier frequency.
3. The last stage of the amplifier should provide an output suitable for driving the dc torque-motor servovalve assembly.

The design basis for the servoamplifier will be described in two parts. The first is a single amplifier stage, Figure 2, that meets design objectives 1 and 2, above. The schematic shows a push-pull vacuum tube stage with input transformer T_1 and an output transformer T_2 coupled to a load R_L. The B+ power supply voltage is depicted as a regular series of square-topped pulses in phase with, and of the same frequency as, carrier f_c; i.e., the B+ voltage is instantaneously zero when the input signal of carrier frequency f_c is zero. The signal grids of tubes V_1 and V_2 are biased to cutoff.

A pure sinusoidal signal $e_a(t)$, of carrier frequency ω_c and of the polarity indicated, is supplied to the primary of input transformer T_1. The grid of V_1 is driven positive during the first half cycle of $e_a(t)$ and a halfwave current pulse $i_1(t)$ is caused to flow through the top half of the primary winding of output transformer T_2. At the same time V_2 is cut off by the bias and signal voltages applied to the signal grid. During the second half cycle, V_2 conducts and V_1 is cut off, while the halfwave current pulse $i_2(t)$ flows in the bottom half of the primary of transformer T_2. Pulses $i_1(t)$ and $i_2(t)$ cause halfwave current pulses $i_1'(t)$ and $i_2'(t)$ to flow from the secondary of transformer T_2 through the load R_L, producing the output waveform $e_L(t)$. For an input signal $-e_a(t)$ (indicated by the dashed waveform in Figure 2) of opposite polarity, V_2 conducts during the first half cycle giving rise to the load voltage $-e_L(t)$ (also dashed). Thus a pure sinusoidal input signal of carrier frequency f_c will be amplified with preservation of its phase relation. The amplifier output is, of course, zero for zero input signal.

Bandwidth characteristics

Now examine the performance of this type of amplifier stage with input signals of the suppressed carrier type. Figure 3 shows the suppressed carrier modulated signal for $f_d = \frac{1}{10}, \frac{1}{2}, \frac{2}{3}$, and $\frac{3}{4}$ of the carrier frequency f_c. Since six cycles are shown for the case $f_d = \frac{1}{10} f_c$

$$6 \text{ cps} = \frac{1}{10} f_c \quad (7)$$

and

$$f_c = 10 \times 6 = 60 \text{ cps} \quad (8)$$

so that the corresponding values of f_d for $\frac{1}{10}, \frac{1}{2}, \frac{2}{3}$, and $\frac{3}{4}$ f_c are 6, 30, 40, and 45 cps, respectively. Figure 4 shows the waveforms of $i_1(t)$ (above the reference line) and $i_2(t)$ (below the reference line) when V_1 and V_2 conduct for the above sets of suppressed carrier input signals. Since $i_1'(t)$ and $i_2'(t)$ are identical with $i_1(t)$ and $i_2(t)$, it can be shown by similar graphical analysis that the output waveforms for $e_L(t)$ are exact reproductions of the input modulated carrier waveforms of Figure 3. Thus the simple amplifier stage of Figure 2 passes the suppressed carrier signals described by Equation 4 as well as pure sinusoidal signals of frequency f_c. The only requirement is that the phase or zero crossover points for the input signals be matched with the

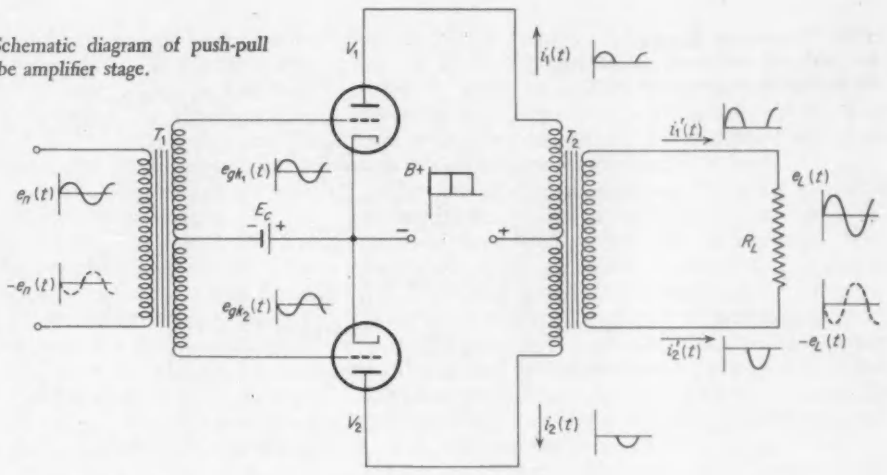


FIG. 2. Schematic diagram of push-pull vacuum tube amplifier stage.

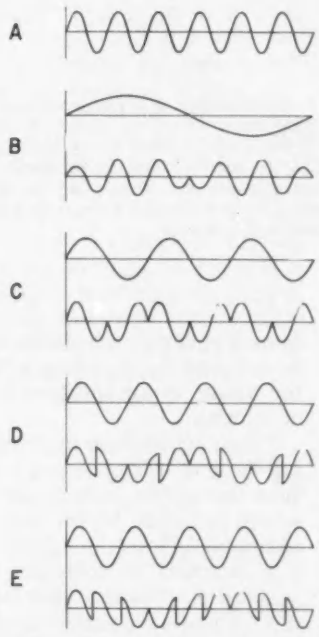


FIG. 3. Waveforms show type of inputs handled by amplifier. A is carrier frequency. B through E are modulating signals and modulated carriers for signal frequencies of $\frac{1}{10}$, $\frac{1}{2}$, $\frac{3}{4}$, and $\frac{3}{4}$ f_c.

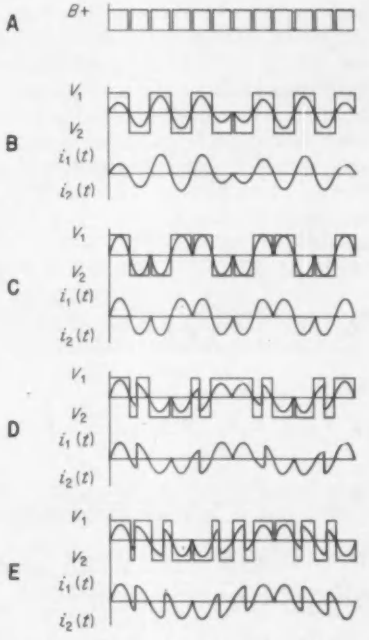


FIG. 4. Graphical analysis of how modulated signals are transmitted by amplifier first stage. A shows the square-topped pulses of B+ supply. B through E are patterns of tube conduction and output current for signal frequencies of $\frac{1}{10}$, $\frac{1}{2}$, $\frac{3}{4}$, and $\frac{3}{4}$ f_c.

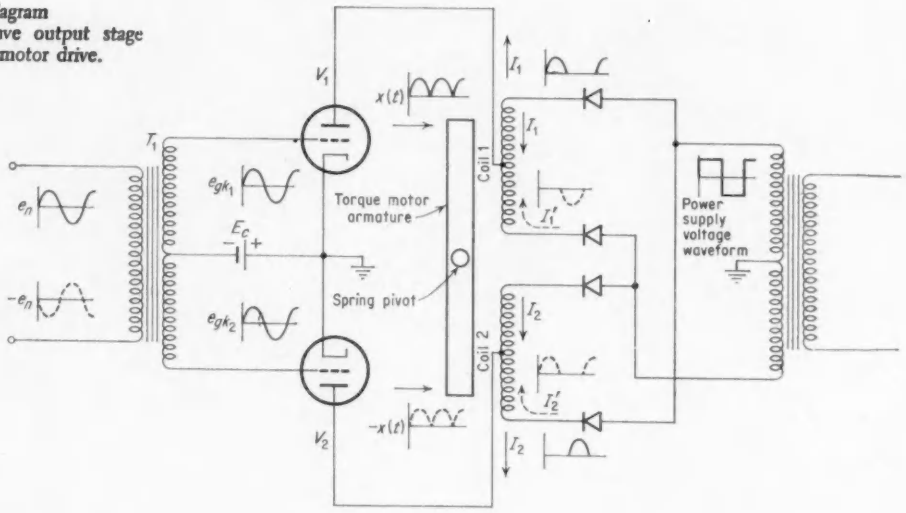
zero amplitude points of the square-topped B+ waves.

This analysis may be extended to signal frequencies that approach the carrier frequency of 60 cps even more closely than 45 cps, although the waveforms become increasingly difficult to predict and recognize. It should be mentioned that for a practical amplifier, particularly for a carrier frequency of 60 cps, extensive demands are made on the input and output transformers. The design requirements for these units may be difficult to meet.

Output stage

The third design objective, an output stage capable of driving a dc torque motor, requires more careful consideration. A circuit for this purpose, with full-wave output, is shown in Figure 5. Here both V_1 and V_2 conduct during each half cycle. Six leads

FIG. 5. Schematic diagram for push-pull full wave output stage for six-lead dc torque motor drive.



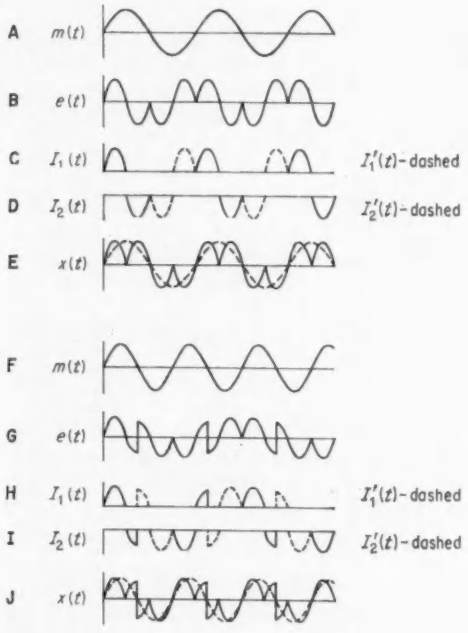


FIG. 6. Reproduction of input waveforms. A—modulating signal with $f_d = 30$ cps. B—modulated signal $e(t)$. C and D—output current pulses ($I_1'(t)$ and $I_2'(t)$ are dashed lines). E—armature displacement, actual and dc average (dashed). Curves F through J represent a similar sequence for $f_d = 40$ cps.

are required on the torque motor. The apparent B+ supply for each tube is a series of square wave pulses similar to that in Figure 2. For an in-phase input signal, V_1 conducts during the first half cycle, and I_1 flows through the top half of coil 1. V_2 conducts during the second half cycle, and I_2 flows through the top half of coil 2. The direction of magnetization produced by the half wave pulses of I_1 and I_2 in the torque motor armature is such that it is deflected in the same direction during both half cycles as indicated by the $x(t)$ displacement waveform. This is precisely similar to the effect that would be obtained by supplying a single winding around the torque motor armature with full wave rectified dc current.

For an out-of-phase input signal, V_2 conducts during the first half cycle and a half wave pulse of I_2' flows through the bottom half of coil 2. During the second half cycle, V_1 conducts and a half wave pulse of current I_1 flows through the bottom half of coil 1. The direction of deflection of the torque motor armature is opposite to that obtained for the in-phase signal above as indicated by the dashed $-x(t)$ displacement waveform.

Figure 6 shows I_1, I_1' and I_2, I_2' waveforms for an $f_d = \frac{1}{2} f_c$ and an $f_d = \frac{2}{3} f_c$. The effective magnetizing current supplied to the torque motor obviously preserves the suppressed carrier modulation envelope of f_c at the higher frequencies as f_d approaches f_c.

Practical transistorized amplifier

A transistorized amplifier incorporating the features described above is shown schematically in Figure 7. The first stage is a push-pull, transformer coupled, common-emitter circuit with unfiltered rectified 60-cycle supply in place of the square-topped B+ supply used in the amplifier of Figure 2. The common-emitter output stage operates similarly to the vacuum tube section of Figure 5. Again, half

sinusoids of 60-cycle voltage rather than square-topped pulse waves are supplied to the output stage power transistors by transformer T_3. The first stage feeds the primary of transformer T_2, which provides base-emitter drive for output transistors V_3 and V_4.

The output connections for driving a six-lead dc torque motor are also given in Figure 7. Half wave currents i_1 and i_1' are shown by solid arrows for the first stage (i_1' in this case being the input current to output transistor V_3 for an in-phase signal). The resulting I_1 for the power output stage is also shown by a solid arrow, as are the currents i_2, i_2', and I_2 during the second half cycle for an in-phase signal. The half wave current I_1 flows through the top half of coil 1 on the torque motor and current I_2 through the top half of coil 2. The torque motor armature is deflected to the right as shown by the displacement waveform $x(t)$ during both half cycles.

For an out-of-phase input signal, V_4 conducts during the first cycle and half wave pulse of current I_2' flows through the bottom half of coil 2. During the second half cycle, V_1 conducts and a half wave pulse of current I_1' flows through the bottom half of coil 1. The direction of deflection of the torque motor armature is opposite to that obtained for the in-phase signal above, as indicated by the dashed $-x(t)$ displacement waveform.

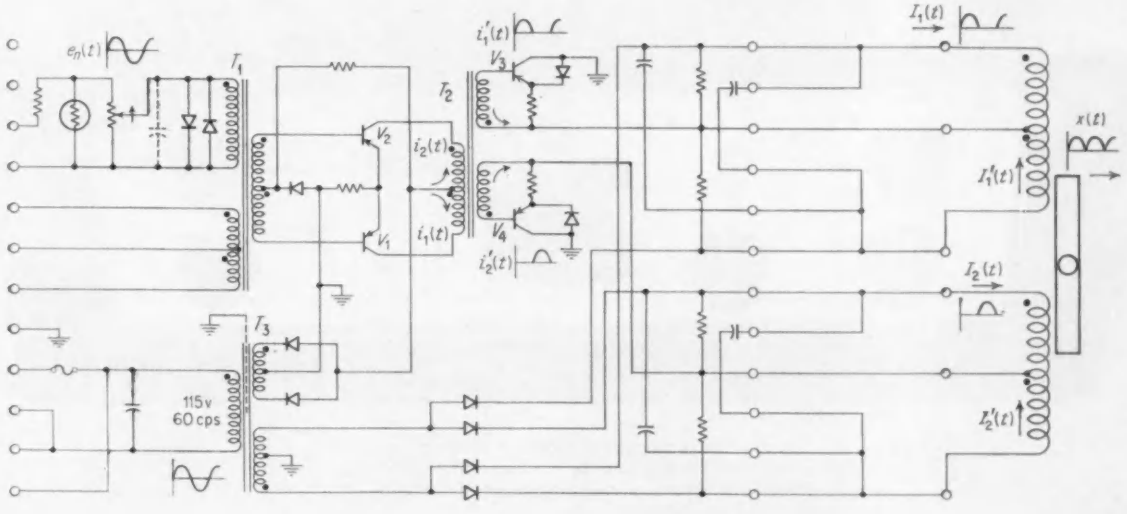
Amplifier test results

Tests run on the prototype amplifier with both 60 and 400-cycle carrier supply and signal voltages have indicated that the output waveforms are faithful reproductions of the input waveforms in spite of the fact that the transistors within the amplifier are supplied with half sinusoids rather than square-topped pulses of B+ supply voltage. The output transformer T_4 is of high quality to reflect the load resistor R_L into the collector circuits of the output transistor with little additional reactive effects. The tests definitely demonstrate that wideband amplification is obtainable for a resistive-type load.

The amount of filtering and damping provided across the torque motor windings has a significant effect on the over-all performance of the unit. The parallel-tuned output circuit represented by a torque motor winding and the 6 microfarads of filter capacity has a resonant frequency of approximately 35 cps. The amplifier-torque-motor frequency response is thus limited by filtering and damping (provided by the output circuit bleeder resistors). Decreasing filter capacity produces a noticeable increase in frequency response (and harmonic content).

A frequency plot of the amplifier and torque motor with 4 microfarads filter capacity and without the bleeder resistors from 1 to 45 cps reveals a smooth contour. This verifies the earlier assumption that the relative phase of the modulation and carrier frequency signals was not important except for the fact that the choice of zero phase angle made recognition of the suppressed carrier waveforms simpler. It must be pointed out that the amplifier-torque-motor frequency response is primarily limited by the characteristics of the dc torque motor load itself. Thus, even raising the carrier and modulated signal frequencies for a particular torque motor to 400 cps yields the same basic response of 45 cps, which at 400 cps is only approximately $\frac{1}{10}$ of the carrier frequency. To realize a bandwidth of $\frac{1}{2}$ of 400 cps, or approximately 266 cps, may well require development of a special dc torque motor.

FIG. 7. Schematic diagram of transistorized amplifier driving a six-lead dc torque motor.



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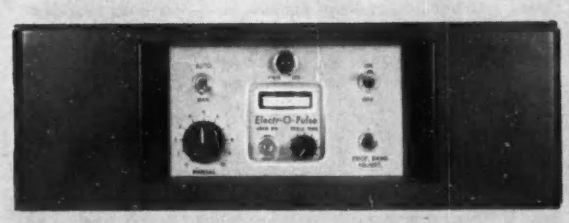

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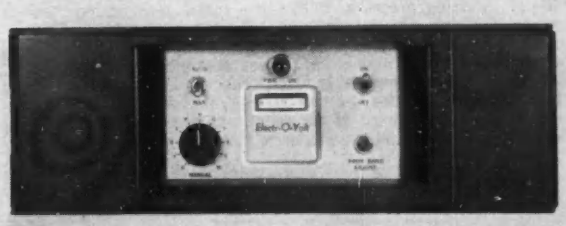

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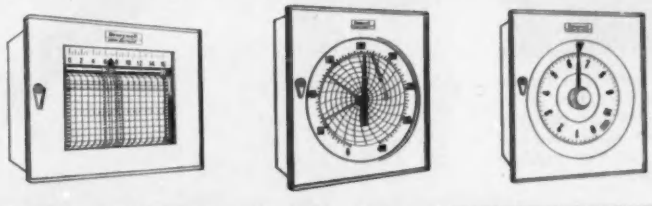

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CIRCLE 145 ON READER SERVICE CARD 145

New Look in Machine Tool Controls

As machine tool control systems grow more complex, the size of the control enclosures continues to increase. In an effort to confine cabinet dimensions to reasonable limits, control designers have been forced to look beyond long established conventional types of machine tool components and construction. The result is that many control packages have taken on a new look, radically different from anything that would be seen on the production floor just a few years ago. Pratt & Whitney Co. has concentrated heavily on size reduction in control design, borrowing some practices from the communications industries. Presented here is a picture sequence highlighting design features of one control system which boasts a ninefold reduction in cabinet volume, greater reliability, and improved serviceability.

MARK H. SLUIS, Pratt & Whitney Co., Inc.

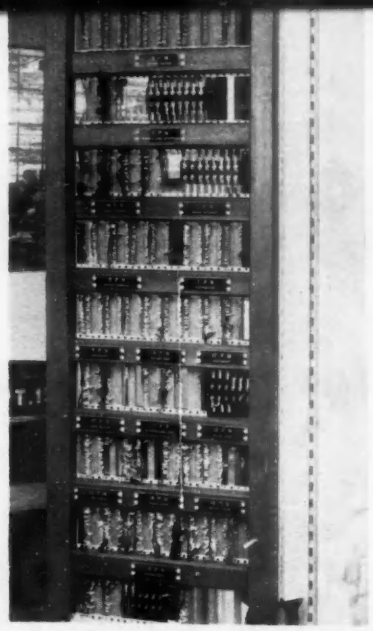


FIG. 2. Terminal board of numeric jig borer control requires about 1,500 connection points, some of which are junction points for as many as four wires. In addition, service considerations make it desirable to have available alongside each termination on this board an auxiliary terminal for the sole purpose of accommodating a test prod point. Conventional machine tool-type screw terminal boards would require a tremendous panel area for mounting this number of terminals and would involve much longer wiring runs. The solution pictured packs 3,000 terminations (half on each side of the panel) in an area of 24 by 60 in. Moreover, the board is located just behind the main cabinet door—an area that had to be left clear in previous designs. The two cabinet doors are interlocked by mechanical levers, which require the terminal board door to be opened last and closed first to prevent access to hot wiring without operating the circuit breaker handle of the main door.

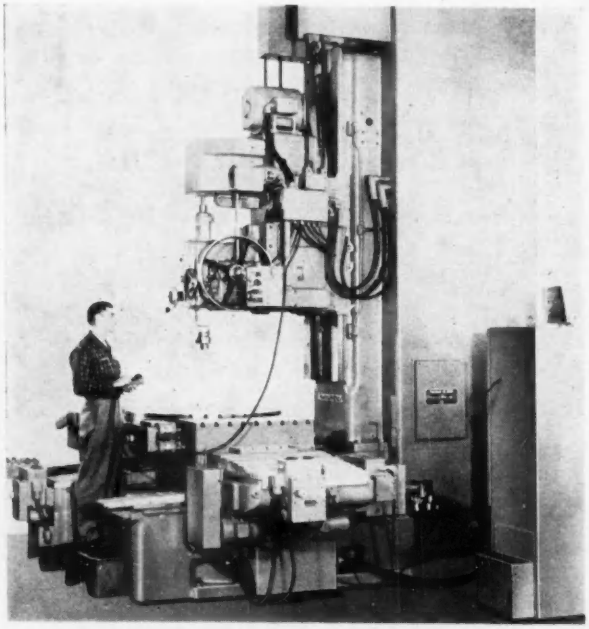
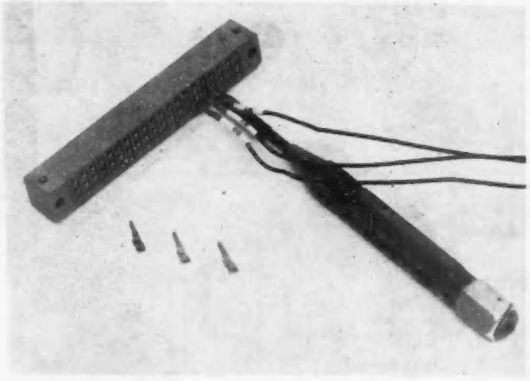


FIG. 1. Huge Pratt & Whitney No. 4EA jig borer can handle workpiece heights of 70 in. and bolt circle diameters of 80 in. Three-axis tape input numerical control system provides fully automatic positioning of the rectangular work-table and the built-in rotary table as well. Operator can also position tables at will by means of telephone-dial input.

FIG. 3. Each side of basic terminal block has 20 triple terminations, consisting of tapered holes that accept mating taper male pins. Each pin is fastened to its lead wire by a crimp joint. A special tool having a spring loaded plunger forces the pin into the block hole and guarantees a uniformity of insertion pressure. Unlike the screw termination, the taper joint actually tightens with vibration and retains electrical stability indefinitely. Because all terminals are available from both sides of the board it was possible to confine the outboard side of the panel to interconnections between chassis and the inboard side to connections between cabinet and machine. During wiring of the panel, prerecorded instructions are played back to the assembler to minimize wiring errors.



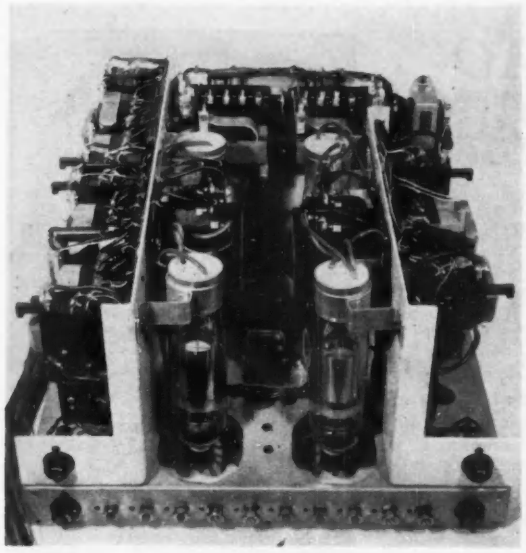


FIG. 4. Mounting across-the-line starters around sides of box-like chassis structure cuts space needed for these components by three-fourths. In conventional machine tool control cabinets, starters are supported on flat panels and all space in front of panel is wasted. Because in the new design the overloads are arranged for automatic reset, it is not necessary to locate the reset buttons for maximum accessibility.

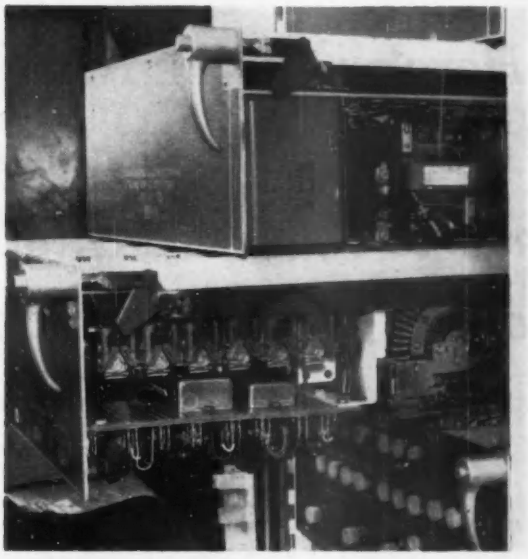


FIG. 6. Inverted chassis hung below sliding drawers make circuits and components accessible for service without disconnecting chassis from system. This design was chosen over the usual type of rack and panel construction wherein chassis can be removed completely. One reason for this choice is that the machine tool industry does not regard quick-disconnects as the ultimate in reliability because use of connectors of any type adds three junction points to every outgoing wire. And many faults in logic circuitry are intermittent and must be looked for while the system is in operation.

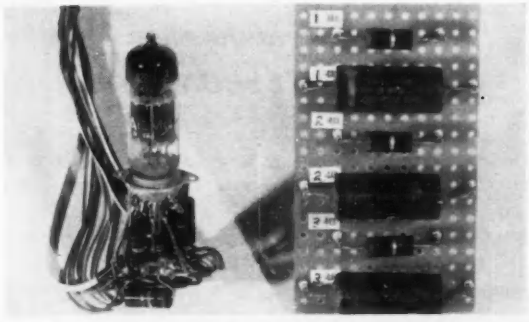


FIG. 5. Turret-type sockets conserve space required for items such as resistors and capacitors and have the added advantage of permitting the short lead lengths recommended for low-impedance electronic circuitry. Where necessary, excess components are mounted on a piece of punched phenolic using single taper pin terminals.

FIG. 7. Mercury wetted relays such as that shown at the right were specified for long life and to provide reliable operation in dry circuits. This type of relay is "gravity conscious" and so is purchased to an upside-down specification to permit its use in the hanging configuration of Figure 6. Bifurcated-contact telephone-type relay, center, is choice for normal low-level switching circuits. All coil voltages are 48 vdc to provide benefits of low power consumption, smaller wire size, and economical ratings for other components. Use of special hermetically sealed taper-pin terminated relay at left is being investigated as possible solution to soldering problems.

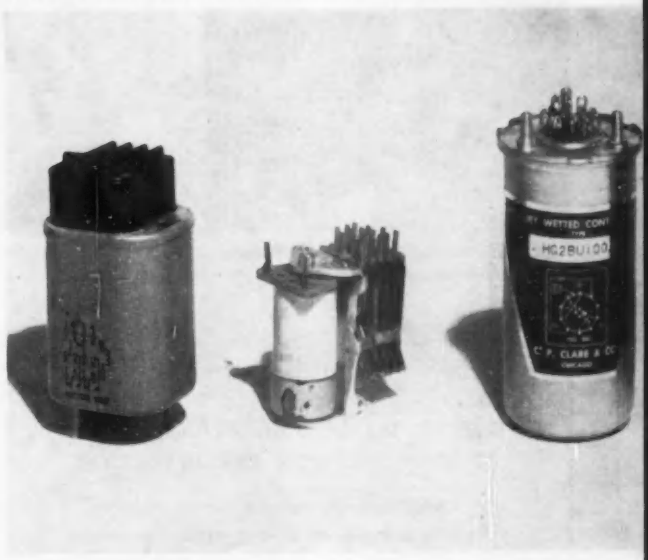
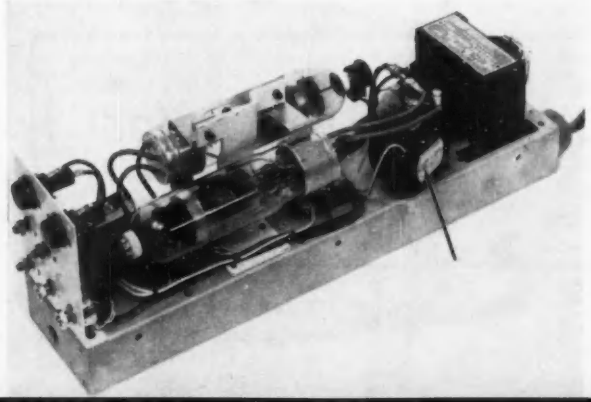


FIG. 8. For maintenance of proper operating temperatures, a 6-in. cooling fan is used to ventilate control cabinet. In addition, small circulating fans (arrow) are used in several places to cool local hotspots.



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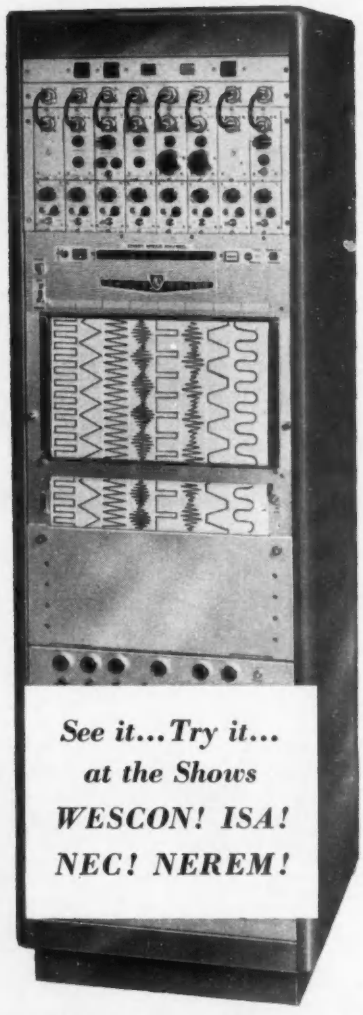

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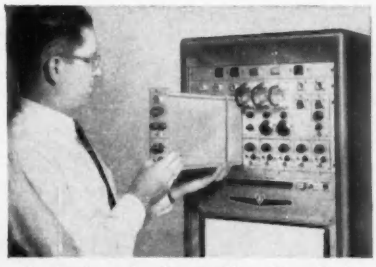
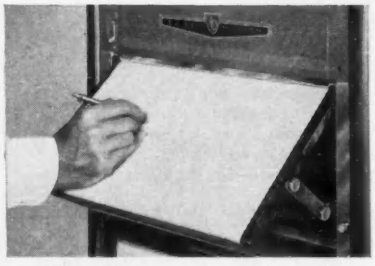
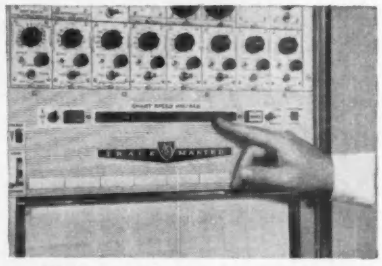


Entire channel easily accessible and completely interchangeable as single unit.



Platen tilts to convenient writing angle.



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Counting Pulses Within the Magnetic Hysteresis Loop

The advent of several new semiconductor thyratron-like devices opens up a new field of miniature pulse-counting equipment. In these the counting occurs within the rectangular hysteresis loop of the core of a small toroid. Pulses may be counted up to 10 or more per counting stage, with automatic reset action to start the next counting sequence at unity. The author describes the basic principles of hysteresis-loop counting, a two-stage circuit for counting up to 100, and an extension to the design of timers and long-term integrators.

T. R. NISBET
Missile Systems Div.
Lockheed Aircraft Corp.

To drive the magnetic core of a small toroid through its hysteresis loop, Figure 1, requires a certain amount of energy—say, 1,000 ergs. Once the core material is saturated, however, only 500 ergs is needed to produce saturation of the opposite polarity. Furthermore, if 50 ergs, not 500, is released in the core, then the residual induction will be reduced by one-tenth of the peak-to-peak saturation flux density. Repeating this operation 10 times again produces saturation, with the operating point moving down the hysteresis loop.

In practice the energy released to the core material occurs by discharging a capacitor through one winding of the toroid. The energy released is $\frac{1}{2} CV^2 \times 10^7$ ergs, where C is the capacitance in farads and V is the voltage change across the capacitor. Figure 2 shows in simplified form the mode of operation. Each input pulse causes the counting capacitor to discharge into the toroid. After the predetermined count or saturation is reached, the second triggering device discharges a reset capacitor. The energy stored in the reset capacitor is sufficient to saturate the core in the opposite polarity and also to produce an output pulse for the next stage.

Figure 3A shows the equivalent counting circuit and the output pulses obtained with resistive and resonant loads. The resistive load for the counter can be the upper base resistor of a unijunction transistor. Even with a resistive load the winding's distributed capacity and the distortion of the hysteresis loop during pulsed conditions cause a voltage spike, Figure 3B, to appear across the load. Care must be taken to assure that the spike amplitude during unsaturated counts does not become so great as to

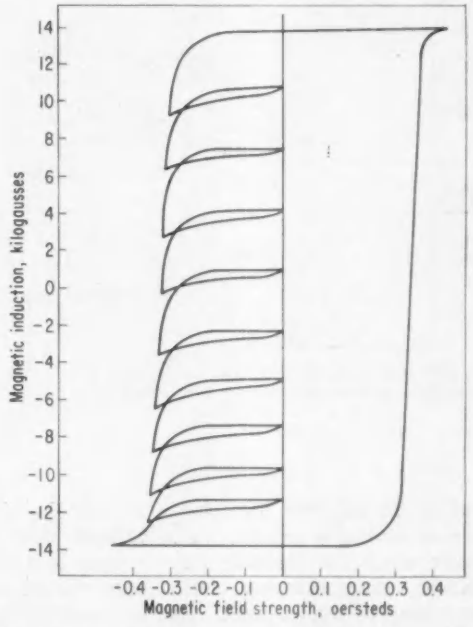

FIG. 1. In the magnetic counter the operating point traces out a pattern of minor loops superimposed on the main hysteresis loop.

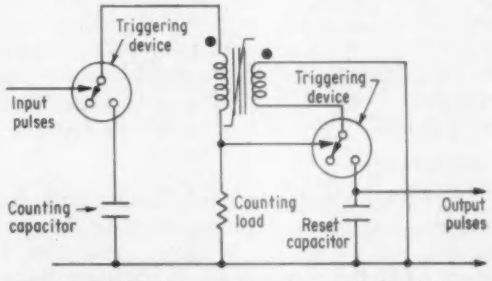

FIG. 2. Mode of operation: each input pulse discharges the counting capacitor into the toroid. When saturation is reached, the second triggering device discharges the reset capacitor to produce an output pulse and to remagnetize the core for the next counting sequence.

inadvertently trigger the transistor of the next stage. One way around this is to use a parallel *LC* load across the transistor emitter, resulting in the transient in Figure 3C. Here, the initial pulse—even if large—is of the wrong polarity to fire the next stage. The backswing pulse voltage amplitude, while of correct polarity, is governed mainly by the amount of energy delivered to the load circuit. During the saturated count the energy is high, creating a voltage large enough to fire the next transistor. With this backswing method the final counting pulse is diminishing when reset action takes place. The action is quite smooth, and the time lag is of no practical significance.

Impedance level

Before describing an actual magnetic pulse counting circuit, two design factors must be considered. These are the determination of the impedance level

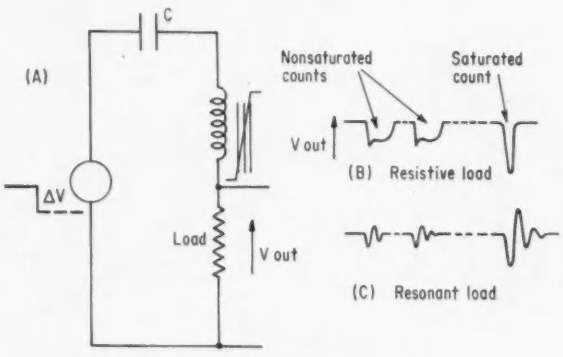

FIG. 3. The equivalent counting circuit and the pulse shapes obtained with resistive and resonant loads.

and of the required core energy. With the objective of finding a suitable value of load resistance, across which the counting pulse appears as a small voltage before saturation and a large voltage after saturation, an approximate value of counting-toroid inductance must be determined. An acceptable value is the mean inductance *L*, determined by measuring the saturated and unsaturated inductance of the toroid (using a small amplitude sine wave) and taking the square root of the product of the two values. Equating the energy stored in the counting capacitor with that which would be stored in an equivalent inductance, $\frac{1}{2} LI^2 \times 10^7$ ergs, the impedance level is seen to be $(L/C)^{\frac{1}{2}}$ ohms.

Core energy

The energy required to drive the core through its hysteresis loop, if not explicitly stated by the manufacturer, can be readily calculated from core loss figures. Let the core loss be *N* watts per lb at *F* cps, or *NF* watts per lb per sec. If the core weighs *X* lb, then the energy is *NFX* joules or $NFX \times 10^7$ ergs. The reset energy is one-half this value, although many times more energy can be used if conveniently available. The energy which must be released by the counting capacitor depends on the scaling factor of the stage. For a count of 10, one-tenth of the minimum reset energy is required. Experimentally, counts of up to 20 or 30 per stage have been obtained with Deltamax cores, but for practical circuits temperature variation of the hysteresis loop makes it desirable to restrict it to 10.

Two-stage pulse counter

Figure 4 is the circuit of a two-stage pulse counter designed to replace 14 transistors in flip-flop stages, with each magnetic stage counting to 10. The cores are 1-mil Deltamax. The number of turns on the counting winding (300 *t*) is not critical, but the supply voltage should be regulated to within a volt. Unijunction transistor Q_1 generates the counting pulse as triggered from the input pulse. The transistor has a specific firing voltage, typically 13 volts in this circuit.

A large capacitor (whose circuit position corresponds to that of the reset capacitors C_3 and C_5 in subsequent stages) is charged to a voltage below the firing level. By adjusting R_1 this can be set at 12 volts, for example. The input pulses to be counted must therefore exceed the 1-volt peak necessary to fire the transistor. The transistor will cease conducting at about 3 volts, the change in voltage across C_1 being 9 volts. The value of the first counting capacitor C_2, assuming ideal components, is $0.2W/V^2$ microfarads, where W is the ergs required for a count of 1 and V is the change in voltage.

Note that the circuit employs the backswing method of limiting the amplitude of the voltage spikes to prevent triggering the subsequent stage except during the saturation count. The circuit also includes a simple method of multistage reset. Here an inductance, a capacitance *C*, and additional windings on the various cores, connected in series, cause all cores to reset when the supply voltage is first applied, because the current surge occurring when *C* is charging saturates all cores. Inductor L_1 prevents a counting pulse in one core from appearing as a count in some other stage.

The counter as shown in Figure 4 responds only to a preset count. To find the number of pulses stored it is necessary to apply additional pulses at the input until the preset count is reached. A faster method is to read out each stage separately.

One unique feature of the device is that the pulse count remains stored without consuming any power. When using unijunction transistors, however, the supply voltage cannot be removed suddenly, or the stored information will be lost. Consequently some switching arrangement is necessary to preserve the count. When using four-layer diodes, as shown in Figure 5, the count will automatically be retained

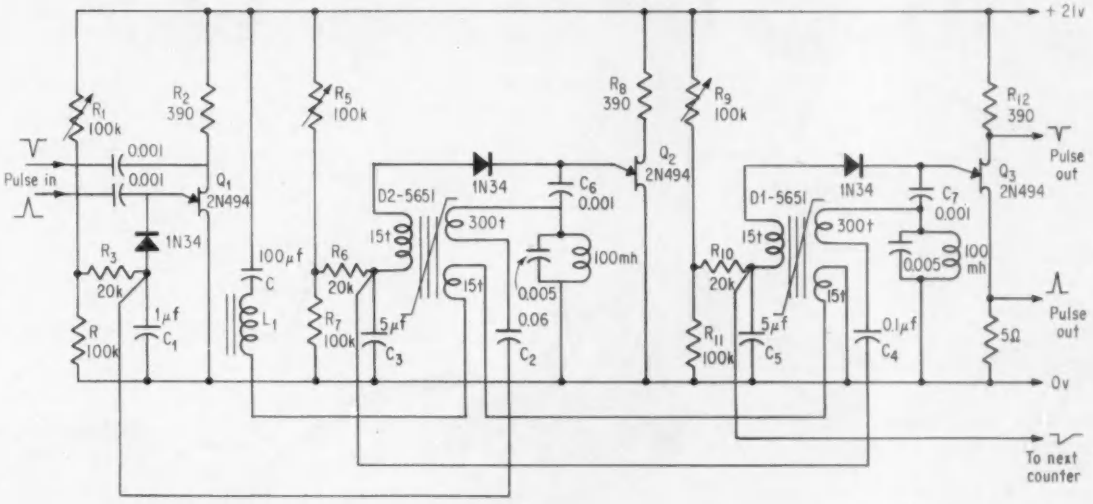

FIG. 4. Typical magnetic counter stores up to 100 counts.

even during supply voltage removal. A switch in series with C then gives the option of having multiple reset or retaining the previous count when the counter is reenergized.

Four-layer diodes also offer good possibilities for miniaturization, particularly because of their reduced power consumption compared with unijunction transistors. Virtually no power is consumed except that required to restore the voltage change of the counting and reset capacitors.

The magnetic counter, as originally designed, does not operate at high speeds. Its main purpose was to replace a multiplicity of transistor flip-flops operating at counting intervals of greater than 1 sec. To attain higher speeds it is necessary to arrange for the capacitors to be recharged quickly, without passing any significant current through the counting toroids. The capacitor size can be reduced by using a higher-voltage switching device, like a 50-volt four-layer diode, or by using smaller (less energy) magnetic cores. Ferrite cores also offer the possibility of increasing counting speed; although, in a general way, high speed and large scaling factors may present conflicting requirements.

Integrator and timer

With slight modification to the circuit shown in Figure 4, the magnetic pulse counter can be made to serve as a miniaturized, long-term integrator. Circuit changes are to make R_1 equal to infinity and time constant R_3C_1 equal to about 15 sec. The voltage signal to be integrated is applied across R_4. The signal builds up across C_1 until the voltage is large enough to fire the first transistor. Each firing marks the attainment of a specific voltage-time integral. The over-all integral is denoted by n, the

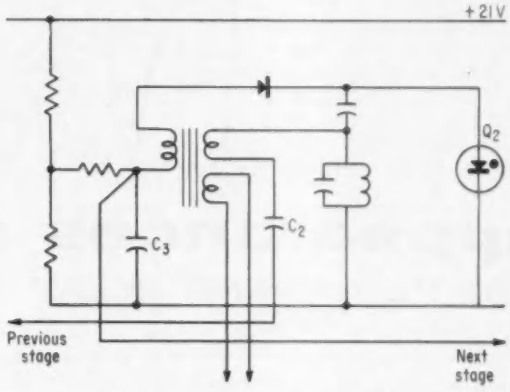

FIG. 5. Four-layer diode Q_2, used in the circuit of Figure 4 instead of the unijunction transistor, requires no power to maintain the stored counts.

number of times the first transistor fires, as stored in the subsequent counting stages. Here each count equals the same voltage-time integral, but the integrating period Δt may be spaced irregularly.

If the voltage being integrated remains constant, the integrating count occurs at uniformly spaced time intervals. The first stage then becomes, so to speak, a pulse generator with a constant frequency. The constant voltage at R_4, which must be larger than the transistor firing voltage, can be obtained by adjusting the ratio of R_1 to R_4. With such a self-generated constant-frequency input pulse, the magnetic counter now serves as a timer, the time delay from input to output depending on the scaling factor of each stage, the number of stages, and the pulse period of the integrating stage.

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AB8AY	DPST-NC	ABC8AY	DPST-NC
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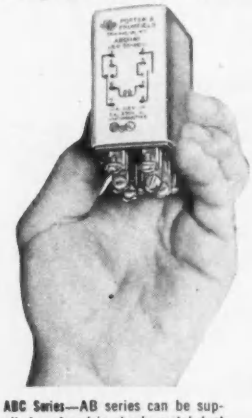

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Life: 3 million cycles (mechanical).
Breakdown Voltage: 1500 volts rms between all elements and ground.
Temperature Range: DC: −55 to +45°C.
AC: −55 to +45°C.
Weight: AB—5 ozs. ABC—7 ozs.
Terminals: Fit ¼" quick-connect terminals, or may be applied to printed circuits using dip soldering. Screw adapters furnished on request.
Enclosure: ABC: Heavy duty dust cover.
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CONTACTS:
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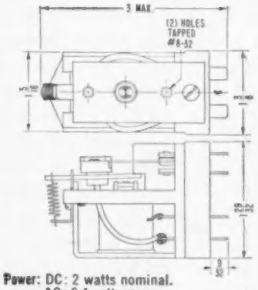
Load: 5 amps at 230 volts AC or 10 amps at 115 volts AC noninductive.
10 amps at 28 volts DC.

COIL:
Voltage: DC: 6 to 110 volts.
AC: 6 to 230 volts.



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AC: 6.4 volt-amps.
Resistance: 35,000 ohms max.
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Beta-Gage Controllers Cut Fabric Coating Waste

Trial runs of beta-gage controllers on leathercloth coating machine reveal 80-percent reduction in rejected material and more economical use of coating paste.

L. E. TAYLOR
Ekco Electronics Ltd. (England)

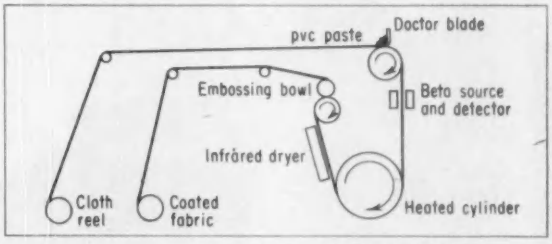


FIG. 1. Leathercloth coating process.

First stage in coating leathercloth backing is to apply an excessive amount of pvc coating paste from the trough, Figure 1. A movable doctor blade then scrapes off the excess paste as the coated material passes under the blade. The two ends of the blade are adjusted to maintain correct coating thickness at each edge of the material, while blade profile determines across-the-sheet quality. In spite of close viscosity and temperature control, large variations in pvc thickness occur if the blade ends must be positioned manually. Time consuming quality control checks consisting of cutting samples from finished sheets and weighing them in the laboratory encourage operators to set the mean coating thickness above specification to prevent underweight production.

Plagued with these difficulties the North Wales plant of Bernard Wardle (Everflex) Ltd.—makers of pvc coated leathercloth—fitted one coating machine with beta-gage controllers on a trial basis, prior to modernizing all of their machines.

Two complete gaging channels were installed on the first coating machine, each channel controlling thickness at one edge of the fabric. Thickness measurement methods are conventional, using thallium 204 sources and an ionization chamber feeding a dynamic capacity electrometer. Setpoint adjustment in the null-balance gage is by means of multiturn potentiometers equipped with 100-in. calibrated drum scales (shown below deviation meters in Figure 2). Meters with a full scale deflection of plus or minus 0.5 oz per sq yd register deviation from setpoint, the deviation signal being applied directly to the controllers.

Control system operation

The control systems are of the time proportional on-off type. The output of each controller drives a fractional horsepower motor with integral gear box to control the ends of the doctor blade. Tests showed that a gear reducer output speed of 0.5 rpm gives a thickness change of 0.1 mil per sec when coupled to the doctor blade positioning mechanism. This corresponds to a weight variation rate of 0.1 oz per sq yd per sec. Control system tolerance is set by changing the controller deadband, a deadband setting of plus or minus 0.15 oz per sq yd corresponding to a tolerance of 1.75 percent at low coating weights and 0.5 percent at high weights. The system responds faster than the previous manual system: full product tolerance of 0.25 oz per sq yd is corrected within 2.5 sec under automatic control.

A simplified version of one control channel is shown in Figure 3. Each of the three control functions—measurement, correction, and reset—is noninteracting and is controlled by a separate linear rundown timing circuit. A polarized relay following the input integration stage determines the polarity of the error signal derived from the gage metering circuits. Relay closure actuates the appropriate output motor contactor and simultaneously starts the correction timer. The output contactor holds in for a preset time determined by the timer controls and the error signal amplitude. When the correction timer times out, the reset timer is triggered to prevent further contact operation during this period. Reset time is adjusted both manually and automatically. On wide speed range machines, tachometer input to the reset timer maintains a constant ratio of machine speed to velocity lag, assuring optimum control over the whole speed range. The input integrator and measurement timer are ganged so that a single adjustment maintains the measuring time at twice the integrator time constant. With this ratio the controller responds to the input signal mean value only, damping system response to random product variations.

FIG. 2. Operator controls for the two gages are lower left and right units below the two gaging boxes. Central pneumatics control the embossing-roll.

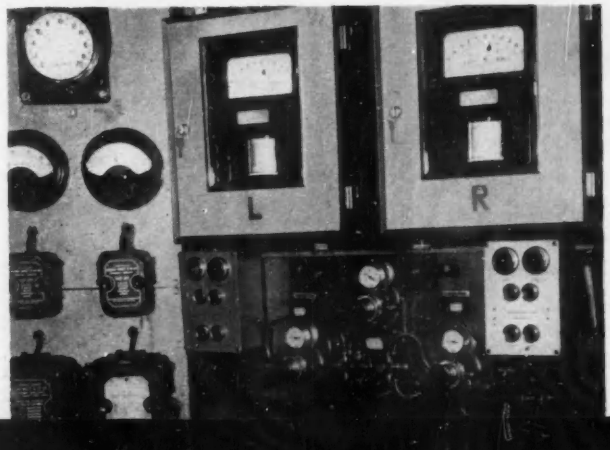
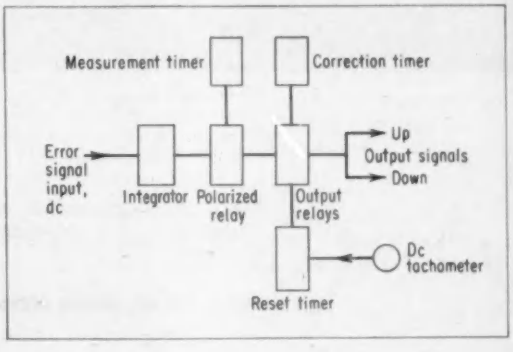
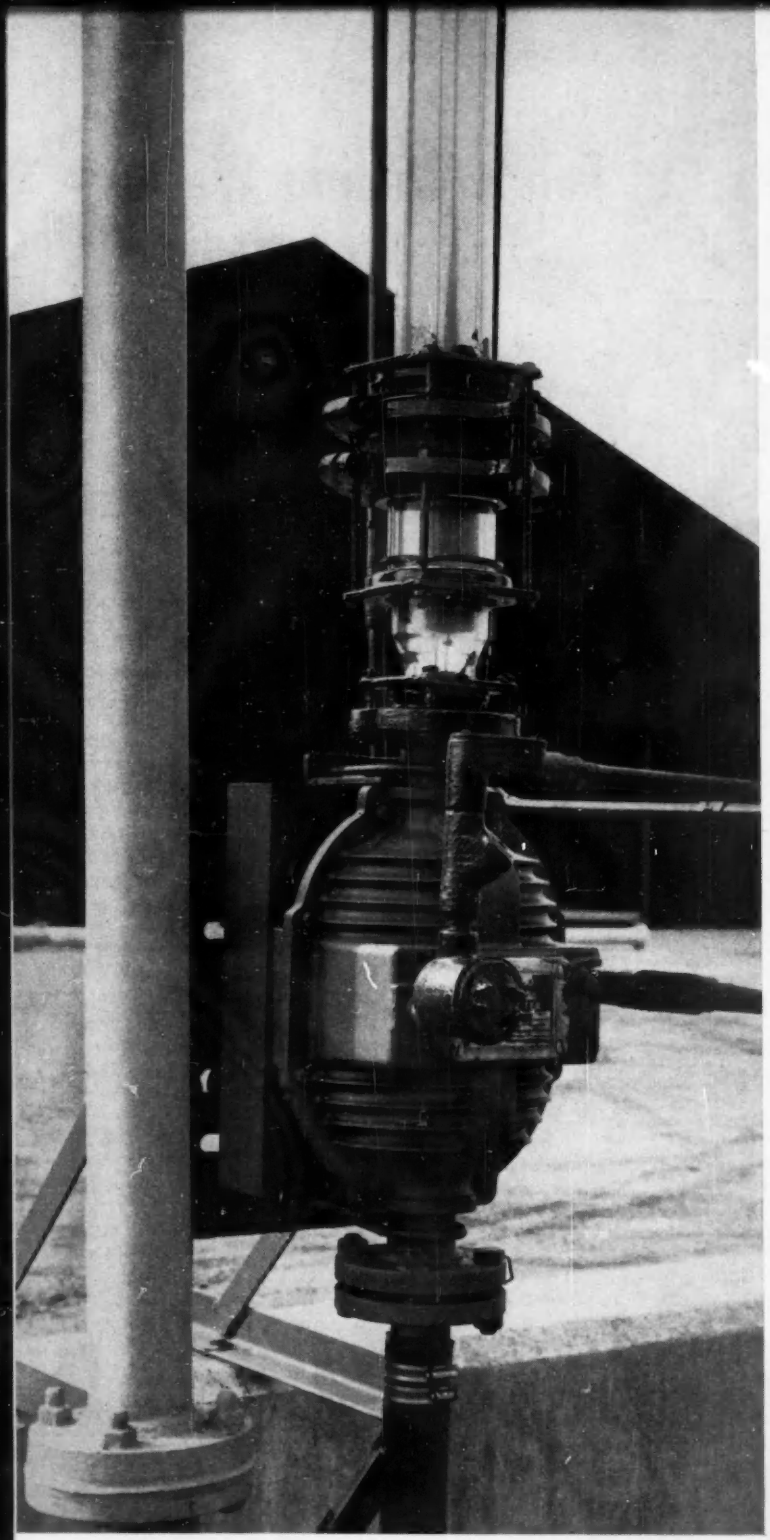


FIG. 3. Time proportional on-off controller.





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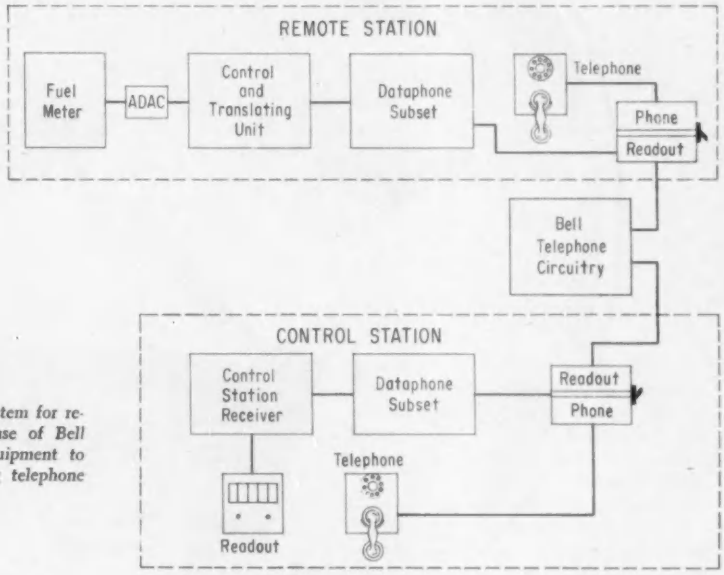


FIG. 1. New telemetering system for remote meter reading makes use of Bell system tone-coded carrier equipment to read meter by simply dialing telephone number assigned to meter.

A simple and versatile telemetering system has been designed by which gas meters or other measuring devices can be read remotely over standard telephone circuits by dialing a telephone number assigned to the remote station and pressing an interrogate switch. The meter reading is then indicated digitally at the home control station within 2½ sec. Thus the system does not require that special lines be laid or leased on a full-time basis.

The new telemetering system also includes two separate error detection schemes to prevent false readings. As a check on the reliability of reading, a gas meter was adapted as required and read by a control console set up in the same room in Chicago. The signal from the "remote" station equipment on the gas meter was then routed to Hawaii and back over standard telephone circuits; not a single error was introduced.

The system and its operation

Figure 1 shows how the new telemetering system uses the low-speed Dataphone tone-coded carrier system available from the Bell telephone companies. A five-decimal-digit shaft to analog converter (Kearfott's ADAC) is geared to the output shaft of the gas meter and delivers parallel digital data to the control and translating unit. Upon command from the control station the control and translating unit reads the digital data serially into the Dataphone carrier system.

Bit-by-bit serial transmission of digital data is used in the Dataphone system to permit sending digital data of any required accuracy over a simple two-wire telephone circuit. To realize the economy of standard teletype transmission over existing telephone lines, the data rate was limited to 15 bits per sec. The ADAC used to digitize the shaft angle output of the gas meter has five drums, each geared 10 to 1 to the next. Each drum carries a four-bit nonambiguous unit-position code representing a decimal digit of the shaft position. All drums simultaneously represent the shaft position to five digits. This simultaneous (or parallel) digital data is converted to serial data by scanning the drums bit-by-bit with a stepping switch as shown in Figure 2 for two of the five drums.

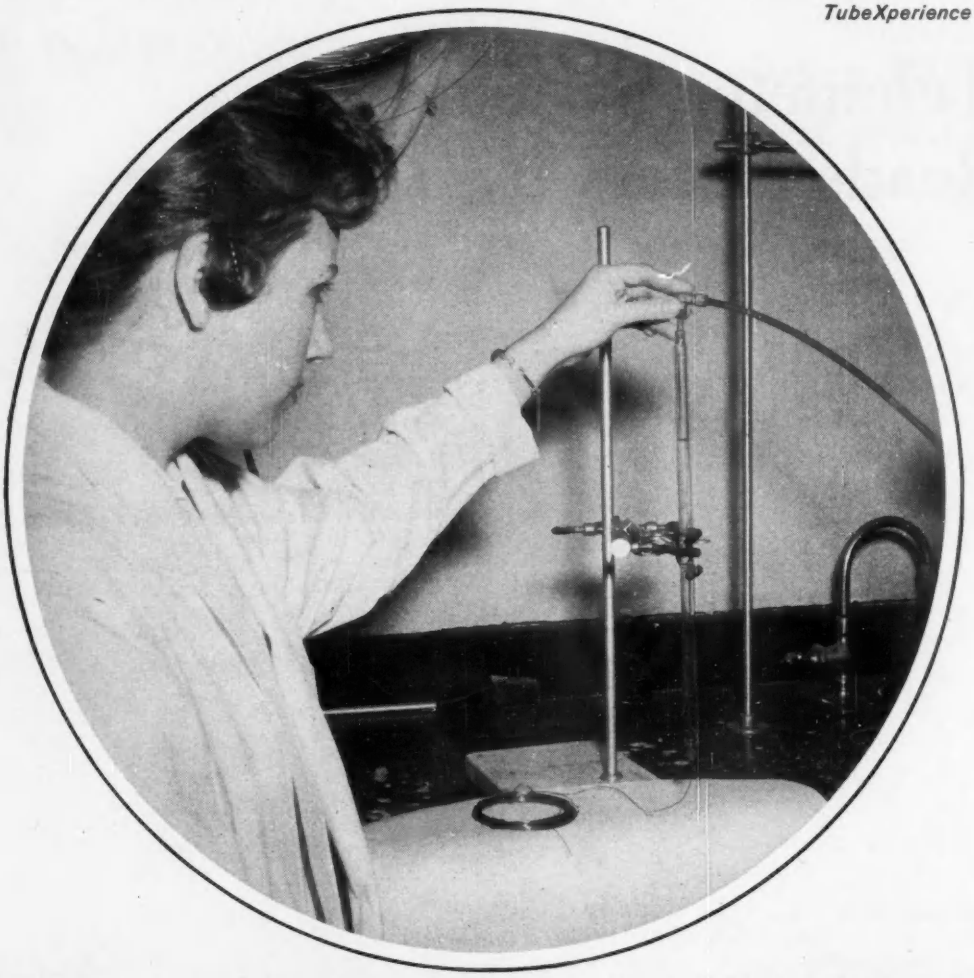
While a stepping switch is much cheaper than a motor-driven commutator, it is difficult to control the scanning speed and sampling periods accurately. Thus it was necessary to provide timing pulses between the information bits to synchronize the relay decoding networks at the main control station with the stepping switch. These timing pulses are generated by the relay multivibrator shown in Figure 2. The coding segments on the drums of the ADAC and the stepping switch contacts both are capable of carrying the 50-volt, 20-ma pulses required to operate the telephone carrier equipment. The serial signal input to the Dataphone system is shown in Figure 3.

The control station consists of a synchronizing module, a shift register, five relay-tree decoding modules, a digital indicating device, and a power supply. The control station accepts incoming data from the telephone equipment and displays it in parallel digital form. The voltage pulses are directed by logic circuits into flip-flop registers which are then read in parallel into the relay tree decoding networks which translate the unit-distance code of the ADAC to the binary code required for each display position of the digital indicator used.

Error detection

Two error detection schemes are built into the system. One is in the shift register and the other in the

TubeXperience in action



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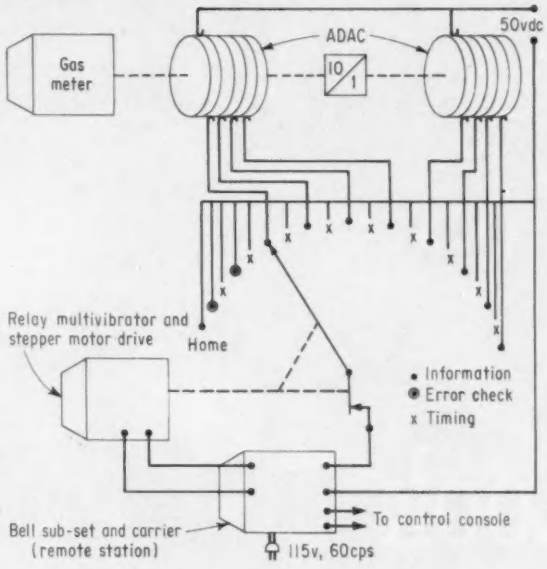

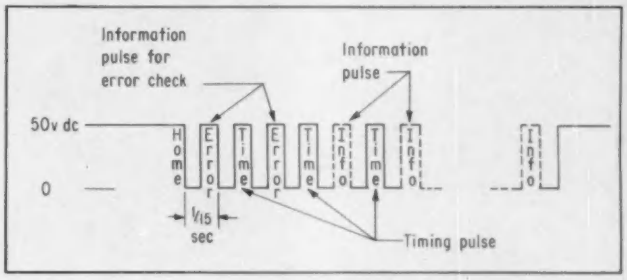

FIG. 3. Sample of pulse train input to telephone carrier equipment.

FIG. 2.
Analog to digital converter attached to gas meter output shaft is scanned by stepping switch which controls telephone carrier subset. multivibrator generates timing signals to synchronize equipment at main control station.

relay-tree decoding module.

Errors are detected in the shift register by processing four extra bits of information for each read-out cycle. These bits are sent through the system by the stepping switch just before the ADAC readout (see Figure 2), and if not transmitted correctly, an X appears on the display unit.

Each relay-tree decoder contains four relays and 10 diodes. Since four bits are used to represent the 10 decimal digits, there are actually 16 possible combinations of the bits. But the relay-tree module is arranged to honor only the 10 combinations which represent the decimal digits zero through nine. If any of the six "illegitimate" codes are received, the logic circuits will display an X in the appropriate digit position on the indicator.

Equipment which the telephone companies presently use to test predetermined lists of telephone lines during early morning hours can be connected to this telemetering system to eliminate the need for manual dialing, and since the meter reading is made available at the control console in both binary and decimal forms, almost any kind of data processing system can be connected to it. It is then only a step to automatic billing.

Telemetered Data Pegs Cause of Bluebird Accident

During his warm-up trials for a new attempt at the world's automobile speed record last month at the Utah salt flats, Donald Campbell's jet car *Bluebird* lost traction with a wet salt surface on one side of the car at a moment of high acceleration. The unbalanced driving forces caused the car to yaw sharply at 300 mph. The *Bluebird* was airborne for 681 ft, and wind forces ripped off the two front wheels while it was in the air. Campbell miraculously escaped injury when the car rolled over six times before coming to a stop. He says he hopes to try again next year.

This complete reconstruction of the cause of the accident was possible because the *Bluebird* carried a 24-channel telemetry system which radioed transducer data back to an observation station at the beginning of the 15-mile track. One of the channels telemetered was transmission rpm, at the rate of eight measurements per sec. This measurement enabled calculation of the car's acceleration at the time traction was lost.

The telemetry system was designed and built by Sir W. G. Armstrong Whitworth Aircraft Ltd., of Coventry, England. The 24 channels included 18 channels of data, with the other four channels used for a synchronizing pulse, grounding, calibration, and a spare. The 24 inputs were scanned in the car by a rotary sampling switch at 12,000 rpm, thus producing 8 samples per sec of any one channel. The composite data from the sampling switch frequency modulated a 145-kc subcarrier applied as amplitude modulation to a 3.5-watt, 460-Mc transmitter.

The transmitted data from the *Bluebird* was picked up by a six-element Yagi antenna on a 45-ft mast, demodulated, decommutated, and recorded on a high speed oscillograph using ultraviolet-sensitive paper which is visible a few seconds after recording. Quickly varying measurements such as strain gage outputs were also displayed directly on cathode ray tubes, and slowly changing ones were indicated on meters.

Data telemetered from the *Bluebird* included the transmission rpm, jet engine compressor rpm, jet pipe temperature, front and rear transmission oil temperatures and pressures, four transmission bearing temperatures, steering track rod position, and the suspension position of each wheel. These last measurements are taken because they indicate the instantaneous aerodynamic characteristics of the car, which the accident emphatically proved very important at high speeds.

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2 Look down

Function Generator Control for Vibration Sweep Testing

J. M. CHIRNITCH
MB Electronics

Sweep-frequency sinusoidal vibration tests usually include one or more amplitude limitations as the band is swept. Combinations of constant displacement, velocity, and acceleration may be required at many points throughout the range, with discrete changes occurring at any point in the frequency spectrum.

The usual method of obtaining some of the common functions is to switch the servo input between operational amplifiers at specific frequencies. Other approaches employ passive networks in the feedback loop to shape the spectrum. Very often, the spectrum is merely divided into parts and tested in sections. But all of these have fundamental limitations, including both accuracy and versatility.

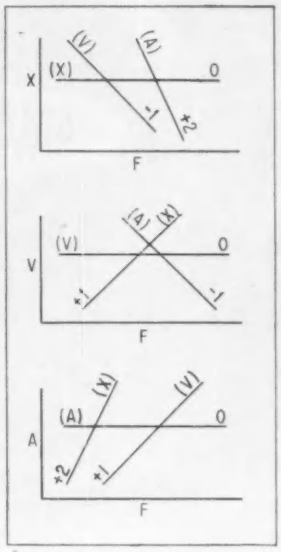

FIG. 1. Basic presentations used in vibration level control.

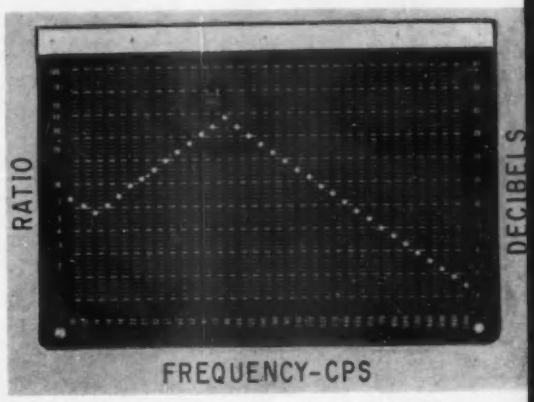

FIG. 2. Presentation on Vernistat function generator is adjusted by hand to represent the required frequency function.

Multilevel control approach

The new MB model N661 multilevel control uses a basically different and versatile approach to the problem. The frequency spectrum is divided into a number of discrete points where switching is available. Similarly, the amplitude is also divided into a number of voltage levels available at any of the frequency points. A linear transition between frequency points is made by an interpolating device.

The basic presentations of vibration level are usually shown on a frequency graph. These are displacement X, velocity V, and acceleration A. On each of these there are lines of constant displacement, velocity, and acceleration, Figure 1. These graphs show that, for a log amplitude function and a log frequency function, the loci will have integral slopes.

The N661 uses the Perkin-Elmer Vernistat nonlinear function generator to control slopes and breakpoints. Any of the graphical plots in Figure 1 can be displayed physically on the control panel of the Vernistat, as shown in Figure 2.

The multilevel control is connected into the feedback loop of the automatic vibration exciter control, see Figure 3. The function generator is an autotransformer with 101 taps spaced logarithmically. The range of voltage values available from these taps is 40 db. Two vertical scales are provided—one from 0 to 40 db and the other a ratio scale graduated from 1 to 100. Thirty-four separate switches are mounted horizontally. In conjunction with the interpolating potentiometer, they provide a log frequency function. The interpolating potentiometer is actually three individual potentiometers synchronized with a switching arrangement which steps along the 34 switch positions. This provides the smooth transition or "interpolation" between switch positions.

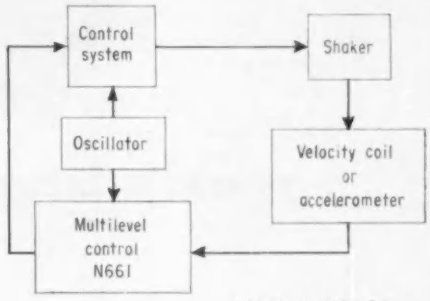

FIG. 3. Multilevel function generator is placed in feedback loop of vibration exciter control system of shaker table geared to oscillator frequency dial.

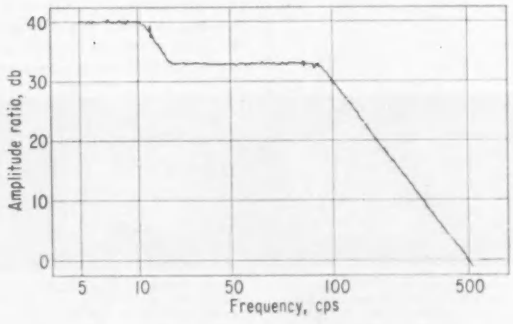

FIG. 4. Plot of actual velocity level at shaker table for typical function.

The Vernistat interpolating potentiometer is geared to the oscilator frequency dial of the automatic vibration exciter control.

In operation the test specification is represented directly on the control panel. Advantage should be taken of the fact that full output of this shaping device is provided when the switches are at the ratio of unity. By setting the lowest point in the representation at unity, full utilization of the 40-db dynamic range is possible. Figure 4 is an actual plot of velocity.

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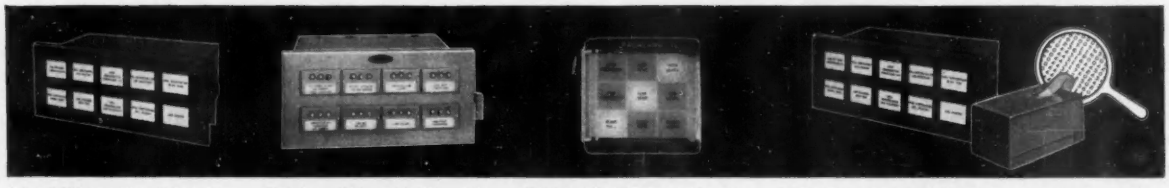

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160 **CIRCLE 160 ON READER SERVICE CARD**

Fail-Safe Circuit for High-Speed Transfer

M. A. KEASAL, JR.
Swift-Ohio Corp.

Because of ever increasing production rates and the demands for rapid transfer of heavy and costly production parts and fixtures, more attention is being paid to "fail-safe" transfer controls which are inexpensive insurance against costly machine damage and scrapped production parts.

The conveyor transfer in this example has an index length of 90 in. and moves four loaded fixtures weighing 400 lb each. The time for index is 1.4 sec, at a rate of 500 per hr.

The prime mover for this system is a 10-hp motor, belt-connected to two gear reducers through a system of electric clutches to give rapid acceleration at startup, a fast transfer, and slow speed for final location.

Figure 1 shows the basic control circuit as it was delivered. When a fixture in position on the transfer closes *LS*1, *CR*1 seals in, energizing the transfer to high speed. After 60 in. of travel, *LS*2 is actuated by a chain mounted dog, latching *CR*2*L* which deenergizes *CR*1, disengaging the fast clutch and engaging the fast brake for the time determined by *TD*1. Upon closing, *TD*1 energizes *CR*4, thus disengaging the fast brake and engaging the slow clutch. When the fixture nears the end of the transfer, *LS*3 is closed, energizing *CR*3 and unlatching *CR*2*L*, disengaging the slow clutch and engaging the slow brake, which assisted by the fast brake, stops the fixture in the unload position at the end of the transfer.

The problem to solve was overtravel, caused by failure of the drive to transfer from high to low speed. This resulted in smashing the fixture against the end of the transfer, causing serious damage to one or more fixtures, and occasional damage to transfer chain pusher dogs.

The circuit was modified as in Figure 2 to improve this condition. *LS*2 was reinstalled to be actuated by a rotary cam driven by the conveyor to eliminate excessive breakage. Also *LS*4 was added to be actuated a very short time after *LS*2. If *CR*2*L* was not latched by that time, *CR*5*L* would latch, stopping the transfer by disengaging the fast clutch and applying both brakes. *CR*5*L* also gives a fault indication. If *LS*4 should fail to function, *CR*6*L* would not latch, thus stopping further transfer motion until the trouble is repaired. Note that the manual control is modified to allow jogging the transfer into final position where the circuit can be reset.

This circuit could also be used on other devices which use an electrically controlled two-speed motion. In the case of the rapid traverse and slow feed control on machine tools it could result in savings on broken tools as well as lost production.

Fig. 1

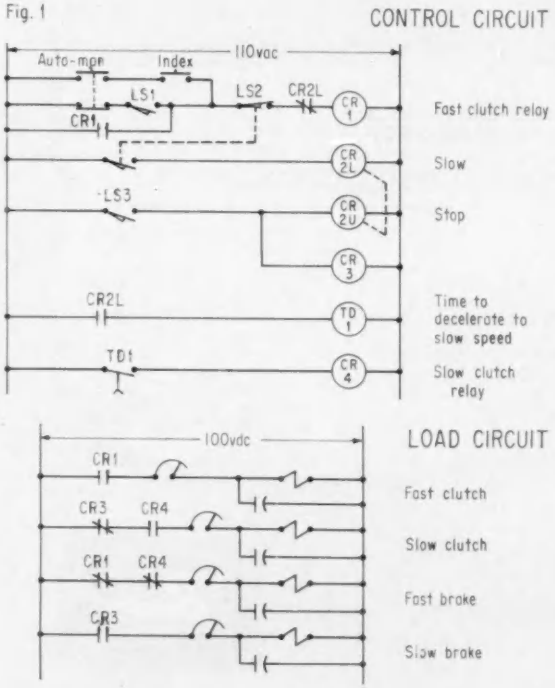
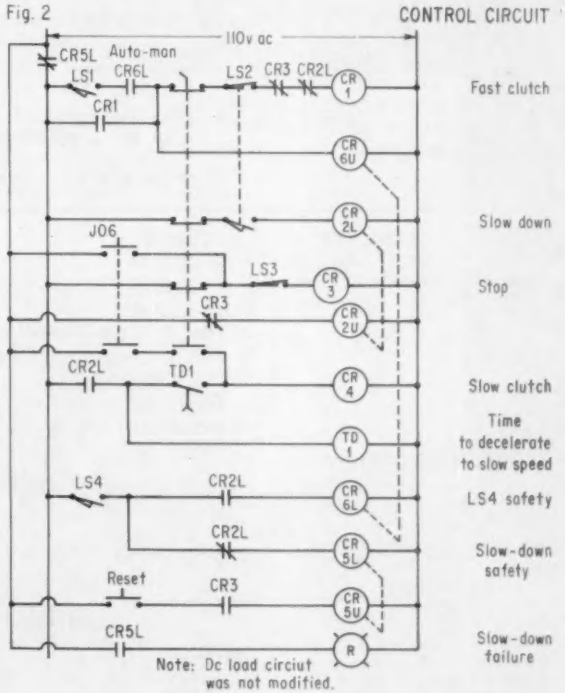
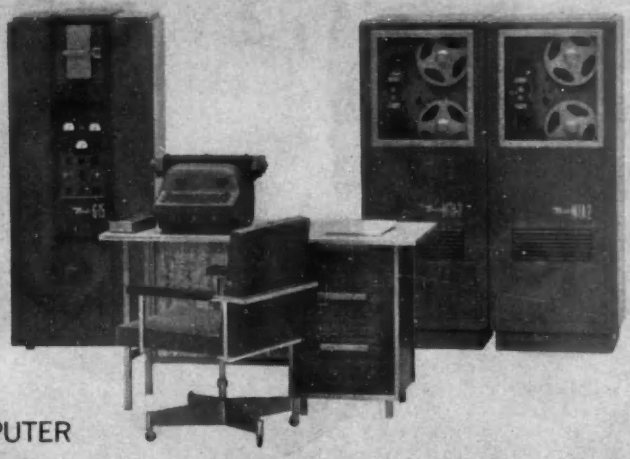


Fig. 2





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(For values of R F & L as specified. For values of E ranging from 100 to 300 in increments of 50. For values of C ranging from .00002 to .000021 in increments of .0000001)

COMPLETE ALGO PROGRAM:

```
BEGIN ⑤
R = 10 ⑤
F = 60 ⑤
L = ₀2 ⑤
FOR E = 100(50)300 BEGIN ⑤
FOR C = ₀00002(₀0000001)₀000021 BEGIN ⑤
I = E/SQRT(R ↑ 2 + (6₀2832 * F * L — (1/(6₀2832 * F * C))) ↑ 2) ⑤
PRINT (FL) = E ⑤
PRINT (FL) = C ⑤
PRINT (FL) = I ⑤
```

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Regulated Tuning Fork Runs Wrist Watches

In the first basically new timepiece design in over 300 years, Bulova has replaced the traditional spring motor-escapement mechanism with a transistorized tuning fork oscillator. The new watch is called the Accutron. It consumes only 8 microwatts and will run for over a year on a $1.50 mercury cell. Timekeeping accuracy is guaranteed within 2 sec a day or 1 min a month—at least 10 times as accurate as a fine quality conventional watch.

Figures 1 and 2 show the mechanism of the new electronic watch. The tuning fork assembly held by the tweezers in the technician's right hand is only 1 in. long and has a small regulator tab which permits shifting the center of gravity of one tine of the fork sufficiently so that the vibration frequency is exactly 360 cps. A tiny jewel-tipped finger attached to one tine of the fork engages ratchet teeth on an index wheel and moves the index wheel one tooth for each cycle of the tuning fork. A second jewel-tipped finger acts as a pawl to hold the wheel during the return stroke of the indexing finger. The index wheel turns a conventional gear train to turn the hands of the watch. The second hand of the Accutron seems to sweep continuously, but is actually stepped along by the index wheel at 360 increments per sec

In normal operation, the total excursion of the index jewel is two teeth. In the "start" position of a cycle it rests against one-half of a tooth. The index jewel retracts one-half tooth, drops to the next tooth, and reacts an additional one-half tooth. On its forward stroke, the index jewel moves back one-half tooth, and engages the tooth from which it had started. This tooth is pushed forward a distance of one-and-a-half teeth. During the first half of the return stroke the wheel backs up and latches against the face of the pawl jewel, and the index jewel returns another half-tooth.

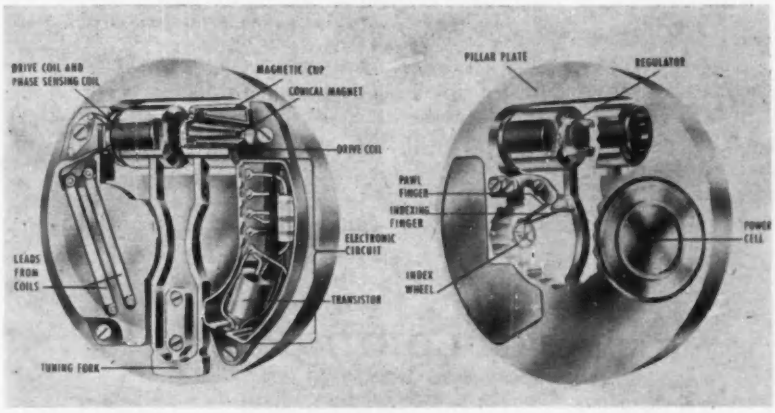
Even if the amplitude of the fork moved the index jewel as little as one tooth-impulse or as much as nearly three teeth, the wheel is advanced only one tooth for each tuning fork cycle because of the relative position of the index jewel on the index wheel and because of the "draw" effect that returns the wheel to the latched position of the pawl jewel during each return stroke. The amplitude of the tuning fork thus can be permitted up to plus or minus 50 percent variation with no loss in timekeeping accuracy.

Figure 3 shows the transistor circuit used to drive the tuning fork. The two drive coils are 8,000 turns each of 0.0006-in. diam wire. Drive coil 1 is tapped at 2,000 turns to derive a phase sensing signal for the emitter circuit of the transistor. The capacitor in this circuit is recharged once each cycle by the ac voltage induced in the phase sensing coil. This recharging current pulse causes the collector circuit to conduct momentarily, thus producing a drive current for the tuning fork at the proper time in each cycle. The capacitor discharges through the resistor during the part of the cycle that the base-emitter diode is cut off.

The series connection of the drive coils and the mercury power cell provides a degree of amplitude regulation in the tuning fork oscillator. Any amplitude variation due to external shock will presumably last for a number of cycles of the 360-cps fork frequency. An increase in amplitude will cause the drive coil to generate a voltage due to transducer action which opposes the voltage of the mercury cell and thus reduces the drive current to the coil. The reverse will occur if an external shock tends to decrease fork amplitude. The result is a much reduced sensitivity to external forces. The design is such that a 10 percent increase in amplitude causes the driving current pulses to become zero, while a 10 percent decrease in amplitude doubles them.

FIG. 1. Tuning fork in right hand carries small pot shaped permanent magnets which move in 8,000 turn coils at bottom of electronic assembly in left hand.

FIG. 2. Tuning fork vibrations drive index wheel through spring finger to turn hands of watch, are controlled by transistorized relaxation oscillator.



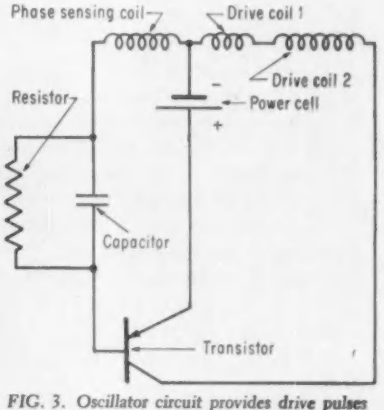


FIG. 3. Oscillator circuit provides drive pulses timed by phase sensing coil. Feedback voltages generated by drive coils from fork motions due to external forces changes drive current pulses to regulate fork amplitude.

автоматический перевод

вычислительные машины способствуют исследованию языков

AUTOMATIC TRANSLATION
INDEXING
ABSTRACTING

To formulate rules for automatic language translation is a subtle and complex task. Yet, significant progress is being made. During the past several years large amounts of Russian text have been translated and analyzed at Ramo-Wooldridge's Intellectronics Laboratories using several types of existing general purpose electronic computers.

Many hundreds of syntactic and semantic rules are used to remove ambiguities otherwise present in word-for-word translation. The considerable improvements that have been effected during the progress of this work indicate that it may be possible within the next year or so to produce, for the first time, machine translation of sufficient accuracy and at sufficiently low cost to justify practical application. Electronic computers are also invaluable for other language research activities at Ramo-Wooldridge.

Techniques for automatic indexing, automatic abstracting, and other aspects of communicating scientific information are also being investigated. Research and development at the Intellectronics Laboratories will eventually lead to electronic machines capable of carrying on self-directed programs of research and analysis and "learning" by their own experiences.

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NEW PRODUCTS

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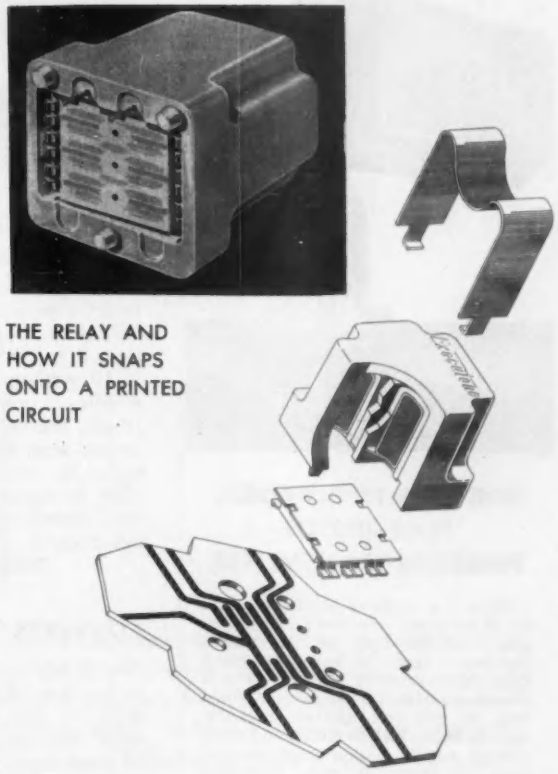
Representing a radical departure from the classical design approach, the Printact relay was developed specifically for use with printed circuits. The first production model, available for 6, 12, or 24-vdc coil operation, measures $\frac{7}{8}$ in. or less on each side, weighs 0.8 oz, and has a minimum life rating of 100,000 to 5 million operations depending on contact load. Armature carries bar palladium contacts in 1, 2, or 3-pole, single or double throw form.

Design of the unit completely eliminates the need for stationary contacts and intermediate connections. Instead it mounts directly on the customer's printed circuit board where the conductors are laid out so as to mate with the movable contacts of the relay armature. Recommended conductor material is 2-oz copper with the immediate contact area plated with rhodium over nickel. A second important design feature is the use of a ceramic permanent magnet instead of a return spring to bias the armature assembly to its deenergized position.

Drawings to the right include a bottom view showing the movable contacts and the coil terminals (the only electrical connection required) and an exploded view showing the quick-assembly spring clip, the magnet assembly and housing, the armature assembly, and part of a typical printed circuit board on which the conductors serve as contacts for a three-pole, double throw switching arrangement.—Components Div., Executone Inc., Long Island City, N. Y.

Circle No. 309 on reply card



THE RELAY AND HOW IT SNAPS ONTO A PRINTED CIRCUIT

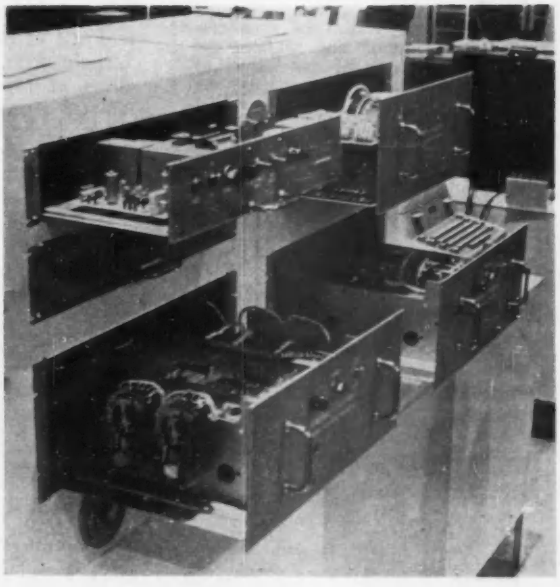
TELEMETERING SYSTEM transmits digital data over existing analog channels.

A new digital telemetering system, designed for time-shared multiplexing with analog telemeter signals, can be used over any intermediate channel equipment, including telephone, telegraph, carrier current, and microwave. System consists of three major components: transmitter, receiver, and programmer. The transmitter accumulates pulses representing an integration with respect to time of the measured variable. At a predetermined time, it converts the number of accumulated pulses into a modified binary code and transmits this in pulse form to the receiver. The receiver then stores the digital code in the form of energized or deenergized relays. Receiver output can operate a visual digital display or, in conjunction with the programmer, operate an electric typewriter or tape punch.

In addition to eliminating the need for a separate channel, the new system provides greater accuracy than that characteristic of integrated analog signals.

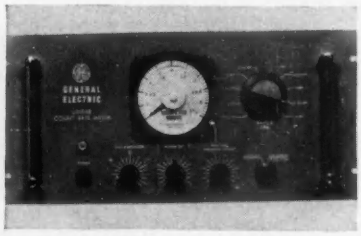
Typical applications include the transmission and recording of power and flow data in the electric utility and process industries.–General Electric Co., Schenectady, N. Y.

Circle No. 310 on reply card



NEW PRODUCTS

DATA HANDLING & DISPLAY



WIDE RANGE, LOW DRIFT

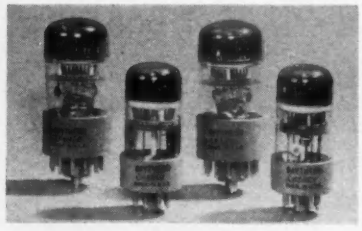
Shown above is the front panel of a new, high reliability linear count rate meter designed to furnish immediate indication of radiation intensities of from 0 to 10 million counts per min in 10 overlapping ranges. Accurate to within 2 percent full scale on all ranges, the rugged instrument has an output zero drift of less than 1 percent. An adjustable trip circuit provides an input for alarm and protective circuits.—General Electric Co., Schenectady, N. Y.

Circle No. 311 on reply card

CONVERTS TAPE

The ZA-753 versatile converter performs three different data conversion jobs: any type of paper tape to magnetic tape, magnetic tape to any type of paper tape, and any type of paper tape to any other type. Speed of reading and punching is 160 characters per sec. A ferrite core memory permits selection of data block lengths up to 720 characters long. A manual-visual check of the mode conversion and memory is incorporated. Converter is 74 in. high, 48 in. wide, and 24 in. deep.—Electronic Engineering Co. of Santa Ana, Calif.

Circle No. 312 on reply card



VERSATILE COUNTERS

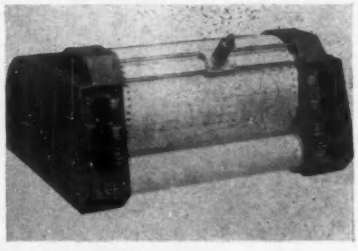
New decade counting tubes now available are suitable for a wide range of applications. Speed of operation can be slow enough to count sorted eggs in a large poultry operation or fast enough to total high speed radioactive pulses in a Geiger counter. The count is indicated on 10 glowing cathodes in luminescent dials within the tubes. Totals can be read visually in units, tens, hundreds, etc. up to 100,000 units per sec. When used for automatic machine tool programming and control and for other high speed processes, the tubes' count is converted to electrical pulses for readout.—Raytheon Co., Industrial Components Div., Newton, Mass.

Circle No. 313 on reply card

MULTIMEG CONVERTER

A new line of analog to digital and digital to analog converters is capable of voltage data conversions at rates from 5 to 30 million per sec. Small size is another outstanding feature. For example, a seven-bit megacycle converter, exclusive of power supply, takes up only 7 cu. in. Conversion time is 020 microsec for six standard models. Both seven-bit binary and eight-bit decimal (8-4-2-1 decade coding) types are available for: a 5-Mcps analog to digital, direct input, positive unipolar; a 30-Mcps analog to digital, direct input, positive unipolar; and a 30-Mcps digital to analog, parallel code input, positive unipolar converter. Conversion error is typically ±0.5 percent or 50 mv, whichever is greater, plus or minus the least significant digit.—Epsco, Inc., Cambridge, Mass.

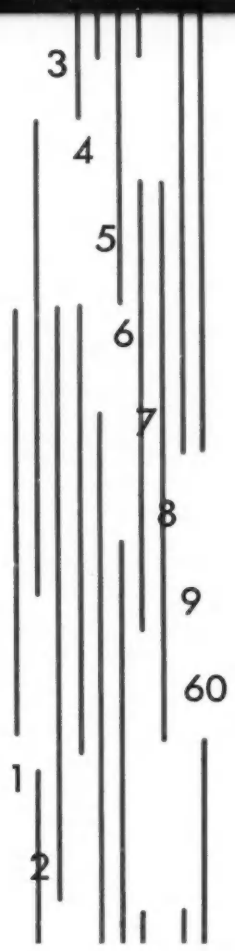
Circle No. 314 on reply card



PLOTS DIRECTLY

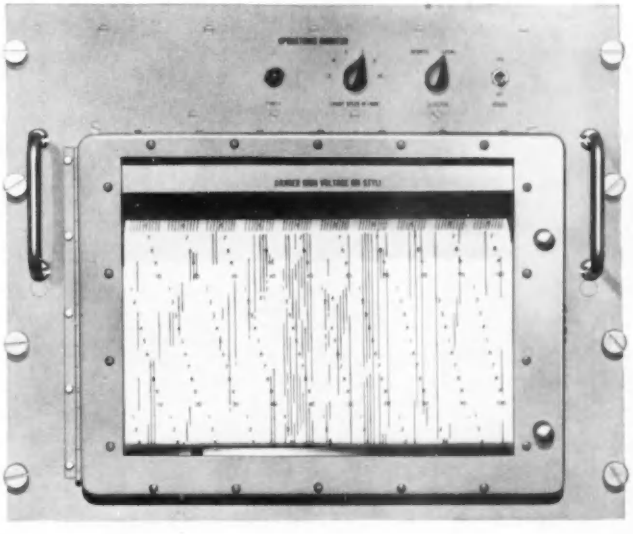
This newly announced X-Y recorder allows precision plotting of computer processed data directly from the computer output. Data from any digital computer can be accepted to give incremental plots accurate to 0.01 in., the size of the basic plotting increment. The plotter can be driven by both punched tape and punched card data processors. Speed of the instrument allows it to provide up to 200 incremental steps per sec, and Z-axis modulation (raising and lowering the

verify events permanently in milliseconds

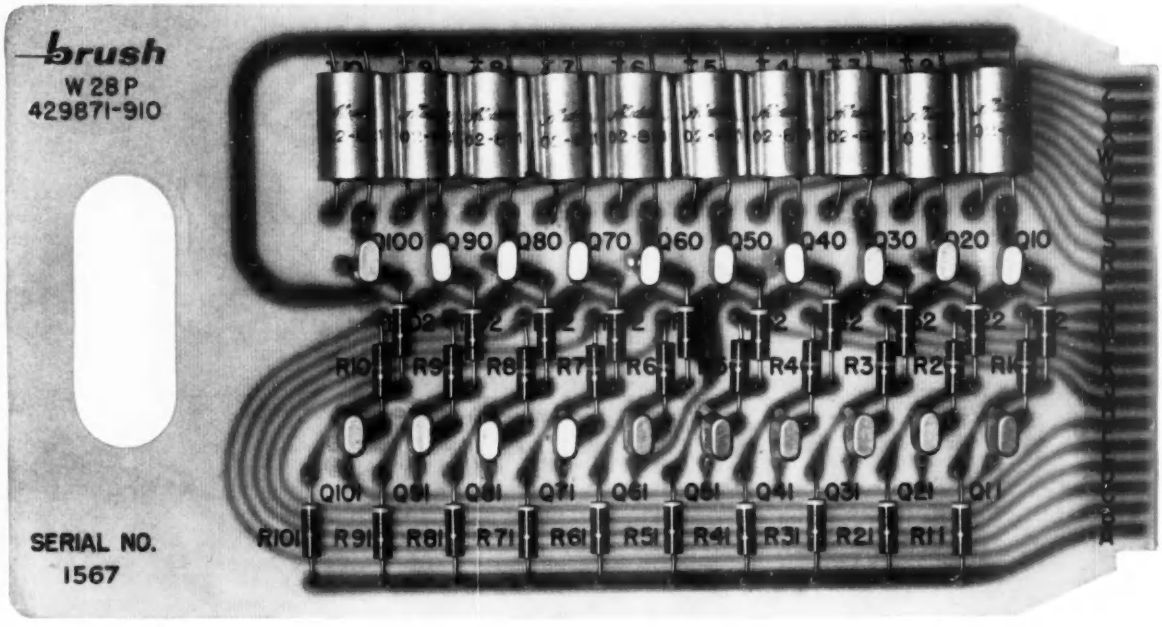


Brush Operations Monitors' response to signals is virtually instantaneous—less than 4 milliseconds. Multiple high-speed events are clearly defined from start to stop, on a common time base—and at rates up to 500 per second. Portable 30 channel or rack-mounting 100 channel models record sharp reproducible traces with fixed-stylus electric writing that provides the utmost in reliability. "Built-in" transistor switching to eliminate relays is optional. No direct writing recording system can match the capabilities of Brush Operations Monitors for industrial and military analysis and control. Write for complete specifications and application data.

brush INSTRUMENTS
DIVISION OF
37TH AND PERKINS — CLEVITE CORPORATION — CLEVELAND 14, OHIO



compact transistor switching for millisecond monitoring



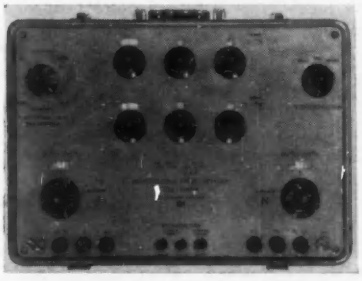
The new Brush Trans-Switcher eliminates relays—greatly simplifies your problems of operations monitoring. Designed to take full advantage of the fast response and high resolution of Brush Operations Monitors, this compact, solid-state switching unit accepts up to 100 different "on-off" signals in a broad range of pulse shapes and amplitudes. Interchangeable, plug-in decade boards are designed to accept different voltage ranges and modes of operation. Avoid the "black box" approach—specify the *standard* Brush Trans-Switcher for the ultimate in precise, reliable monitoring. Write for complete details.

brush INSTRUMENTS
DIVISION OF
CLEVITE CORPORATION
37TH AND PERKINS — CLEVELAND 14, OHIO

pen) can be maintained to 10 operations per sec. Positive or negative polarity pulses with amplitudes greater than 10 volts and rise times less than 10 microsec from source impedances less than 500 ohms will drive the recorder. Completely transistorized with self-contained power supply, the unit measures 12 x 18 x 14 in. (h, w, d) and weighs 40 lb. Price: $3,300.—California Computer Products, Inc.

Circle No. 315 on reply card

RESEARCH, TEST, & DEVELOPMENT



UNIVERSAL POTENTIOMETER

Suitable for lab or industrial use, this new universal ac potentiometer can be used for a wide range of measurements that would otherwise need several expensive special measuring devices. Useful not only for potentiometric measurements, the instrument is capable also of absolute measurements: voltages, 0.05-500 volts; currents, 0.0005-20 amp; resistance, 0.005-2 megohms; inductances, 20 microhenries to 80 henries; phase angles; and capacitance at high voltage (with standard capacitor), 1 micromicrofarad to 1 microfarad. Error limits, except for phase angle, are ±0.1 percent. Ratio measurements can also be carried out. The instrument is manufactured by the German firm, Hartmann & Braun AG. Price: $1,875.—Epic, Inc., New York, N. Y.

Circle No. 316 on reply card

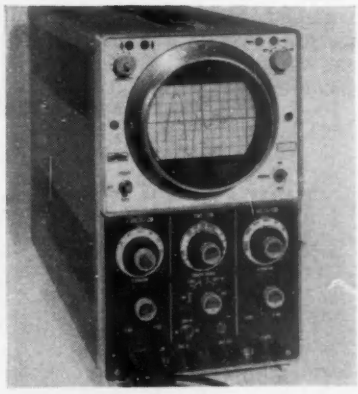
AWARD WINNER

Winner of a design award for the second straight year at WESCON, the manufacturer was commended this year for its Half-Percenter, a line of expanded scale ac or dc voltmeters with error of ±0.5 percent or

NEW PRODUCTS

better. The 3½, 4½ or 5½-in. meters will sell for less than $30 in quantities of 500 or more.—Voltron Products, Inc., Pasadena, Calif.

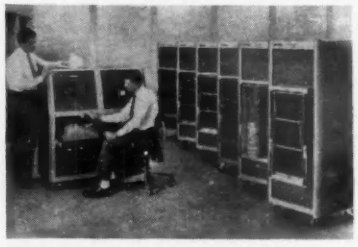
Circle No. 317 on reply card



RETAINS TRACES

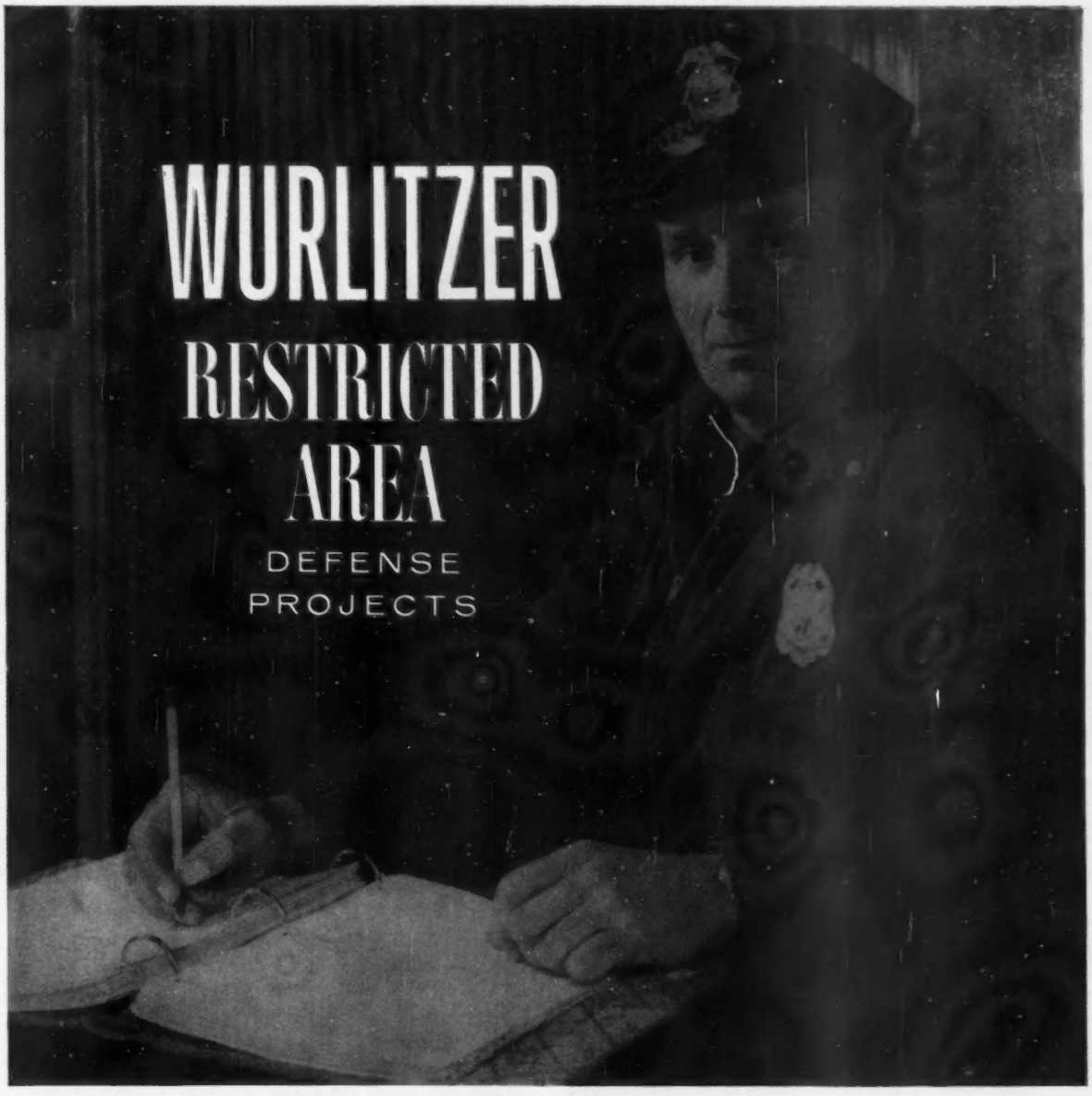
Oscilloscope patterns are frozen instantly on the face of the cathode ray tube of this new Storescope for periods of from minutes up to days. Although prices have not yet been announced, the new tool is said to be priced far below any other storage scope on the market. The conventional mesh-type tube is not used. Instead, a phosphor is employed producing a dark trace on a light background. Storage time is determined by ambient temperature and density of recorded trace. Image is retained even if there is line voltage failure. Writing speed is 30,000 cm/sec. — Allen B. Du Mont Laboratories Div., Fairchild Camera and Instrument Corp., Clifton, N. J.

Circle No. 318 on reply card



TESTS AUTOMATICALLY

The Adept 400 tester makes possible automatic dynamic testing of component subassemblies or complete system checkout. Control of 295 signal, power, and test control lines with punched tape programming allows



NURTURING NATIONAL SECURITY

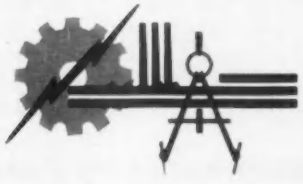
Since World War II Wurlitzer has continued to focus a sizeable segment of its research, engineering and production facilities on equipment for national defense. Today its capabilities in the field of miniaturized electronic components are recognized by their inclusion in six major missile systems. If you seek sophisticated assistance in furthering your contributions to the future of the free world, you'll find Wurlitzer "on the ready."

Inquiries Invited

ELECTRONICS AND DEFENSE PRODUCTS DIVISION

THE WURLITZER COMPANY

North Tonawanda, N.Y.



WURLITZER Research Engineering Production

CIRCLE 171 ON READER SERVICE CARD 171

complete testing flexibility. The manufacturer claims the tester provides greater capability at less cost than any other automatic go/no-go checkout system on the market.—Ortromix, Inc., Orlando, Fla.

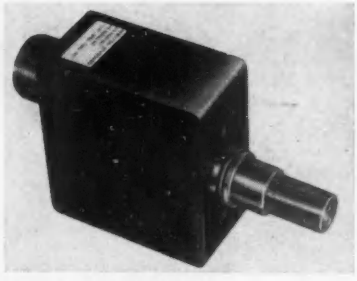
Circle No. 319 on reply card

CHECKS PARAMETERS

A line of electronic system analyzers for automatically checking *R*, *L*, and *C* parameters in any combination now available. The systems are built on the modular concept so that comparatively simple modules check hi pot, leakage, continuity, impedance, voltage, etc. in automatic sequence. A few or up to 1,000 circuits can be accommodated.—A. W. Haydon Co. of Calif., Culver City, Calif.

Circle No. 320 on reply card

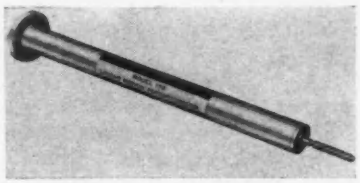
PRIMARY ELEMENTS & TRANSDUCERS



NO CAPACITORS

The new liquid level indicator shown above does not depend on capacitance to measure lubricants and other liquids on aircraft and industrial engines and on a wide range of processing equipment. Elimination of capacitors—with their limited temperature and vibration tolerance—enables the indicator to operate reliably under severe conditions. Tested on a jet engine, the device functioned accurately after more than 200 hr of high temperature operation. The element will perform in liquids for which capacitive, photoelectric, and mechanical sensors are not suitable. When level drops to a predetermined point, the indicator flashes or sounds a warning.—Electronics Dept., Hamilton Standard, Broad Brook, Conn.

Circle No. 321 on reply card



FITS INSIDE ACTUATORS

This linear motion potentiometer is designed for internal installation in hydraulic actuators and other telescoping assemblies. The ½-in. diam case with concentric actuating shaft is sealed against contamination for operation in hydraulic fluids. The pot element is available with either platinum alloy or low temperature coefficient resistance wire. High temperature materials yield high stability and long life during operation at 400 deg F. Standard travel ranges are 1-5 in. Resolution is to 0.001 in.—Bourns, Inc., Riverside, Calif.

Circle No. 322 on reply card

FOR LINEAR OR ROTARY USE

A low cost motion detector that can sense rotary motion at less than ½ rpm, this new device can also be used to detect linear motion after simple conversion. Operable in a wide temperature range—from −40 to +240 deg F—the unit is also unaffected by magnetic fields. Originally developed to detect "creep" of automatic transmission equipped automobiles, the device is now being offered for industrial uses. — Research Div., Gaylord Products, Inc., Chicago, Ill.

Circle No. 323 on reply card

PLUS . . .

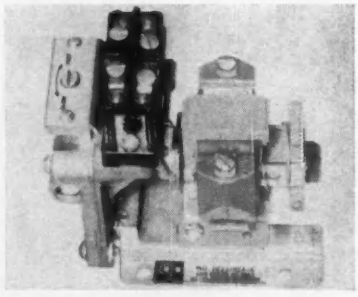
(324) A new solid state strain gage **pressure transducer** that combines the best over-all characteristics of both standard strain gage and potentiometer-type units but has none of their inadequacies has been announced by **Fairchild Controls Corp.**, Sub. of Fairchild Camera and Instrument Corp., Hicksville, N. Y. . . . . (325) **Consolidated Controls Corp.**, member of the Condec Group, Bethel, Conn., has placed on the market a new series of

NEW PRODUCTS

differential pressure transmitters designed for use in primary plant instrumentation. . . . (326) Indium antimonide photoconductive **infrared detectors,** sensitive in the intermediate infrared spectrum, have been added to the product line of **ITT Laboratories,** Ft. Wayne Ind.

Circle No. 324, 325, or 326 on reply card

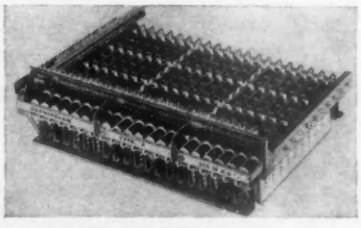
CONTROLLERS, SWITCHES & RELAYS



1-MINUTE TIMER

Key feature of this unique 1-min pneumatic timing relay is simplicity. The device incorporates a diaphragm assembly which eliminates the need for an exhaust valve. Exhaust air is blown back through the intake filters to keep the timer free of dust which may collect. Positive, accurate adjustment of time settings is possible over a range from 0.2 to 60 sec.—Cutler-Hammer, Milwaukee, Wis.

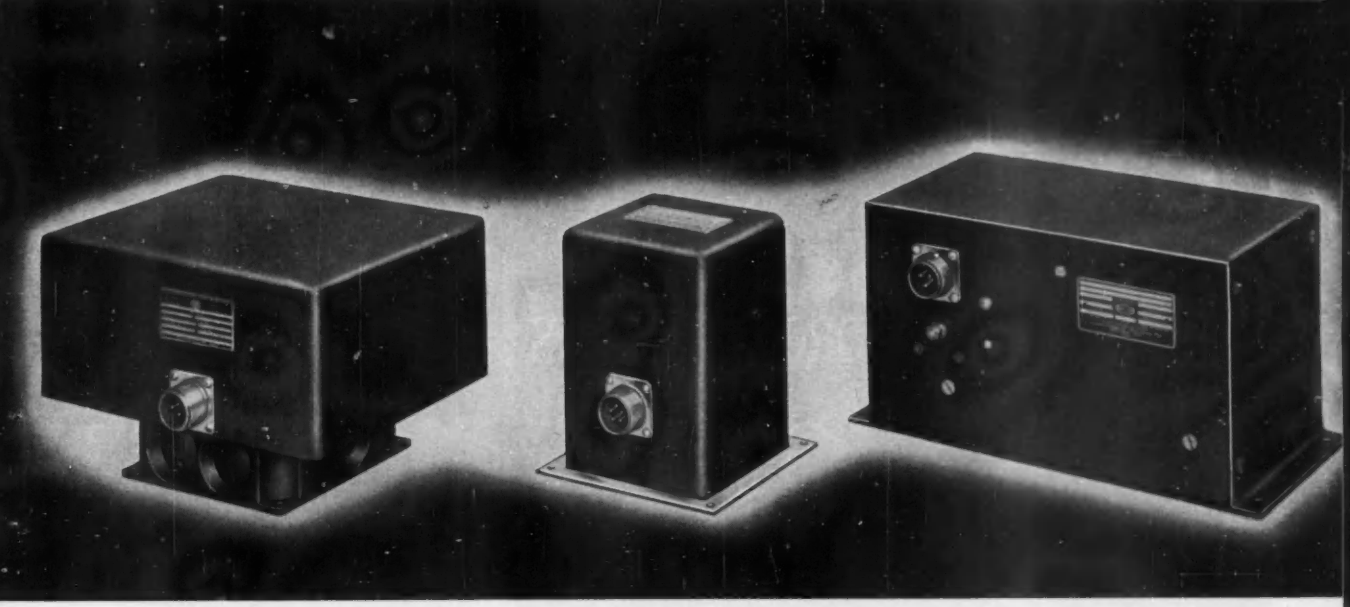
Circle No. 327 on reply card



DO NOT DISTURB

A new crossbar switch is the first commercially available crossbar switch to use Form C contacts. These contacts allow components under test to be monitored without disturbing test conditions; the switch breaks one contact and makes another. The switches are available in various combinations

←CIRCLE 174 ON READER SERVICE CARD



Where can you use solid-state inverters with performance like this?

- **Wide operating temperature ranges**—Models now available and in development, designed for ambients ranging from a low of −55°C to +125°C.
- **Closer frequency regulation**—As close as ±0.02 cps under full load at ambients from +60°F to 175°F in some models.
- **Voltage regulation to ±0.87%** under full load at ambients ranging from −20°F to +175°F.
- **High-power-conversion efficiencies** under full load 28v dc input.
- **Protection against output overloads**—100 va models will withstand 100 va overloading, for 10 minute periods once an hour.
- **Transient voltage suppression**—Transient suppressor removes or attenuates voltage spikes—safeguards semi-conductor elements.

Features like these, in addition to small size and high power output-to-weight ratios, make Hamilton Standard static inverters ideal for such military and commercial applications as:

- aircraft emergency power supplies
- missiles, satellites
- gyro and instrument power supplies
- stand-by power for remote stations
- mobile equipment power supplies
- industrial computer power supplies

Hamilton Standard static inverters have already been chosen by the three principal military services. A variety of 100 and 500 va models, single- and three- phase, are now under development.

CHARACTERISTICS OF 100-VA STATIC INVERTERS

CATALOG NO.	ECB-1.1-AA	ECB-1.1.7-AA	ECB-1.1.13-AA
Output			
Voltage	115v ±1v	115v ±5%	115v ±5v
Frequency	400 ±¼ cps	400 cps ±1%	400 ±1%
Phases	Three	Three	Single
Transient protection	Yes	Yes	Yes
Input Voltage			
Nominal	28v dc	28v dc	28v dc
Range	18–29v dc	20–29v dc	18–29v dc
Dimensions	5"x6"x8¾"	5"x6"x7⅞"	5⅛"x5⅛"x8⅝"

Complete specifications and data are available on these and other Hamilton Standard static inverters from 100 to 500 va, single and polyphase.

HAMILTON Electronics STANDARD

HAMILTON STANDARD

DIVISION OF
UNITED AIRCRAFT CORPORATION
ELECTRONICS DEPARTMENT
BROAD BROOK, CONNECTICUT

ENVIRONMENTAL CONDITIONING SYSTEMS • ENGINE & FLIGHT CONTROLS
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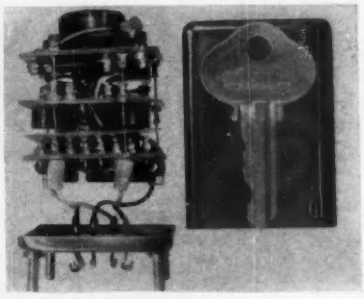
CIRCLE 175 ON READER SERVICE CARD

NEW PRODUCTS

of Form A and C contacts and in 10 x 10 six-pole and 20 x 10 six-pole matrices. Up to 3 amp can be carried by the contacts.—James Cunningham, Son & Co., Inc., Rochester, N. Y.

Circle No. 328 on reply card



LAYER CAKE RELAY

Employing a new type of modular layer construction that allows quick design modifications, this new solid state relay has a life expectancy on the order of millions of cycles. Weighing only 10 oz, the units' small size is shown in contrast with a door key, above.

Characteristics:

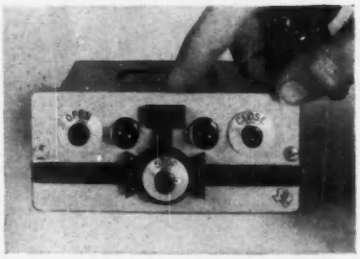
Max operating current: 60 ma @ max operating voltage, 30 vdc
Pickup voltage: 16 ± 2 volts @ 25 deg C
Dropout voltage: 9 + 2, – 1 volts @ 25 deg C
Contact rating: 1 amp resistive or inductive @ 28 vdc
Operate time: approx 10 microsec
Release time: approx 50 microsec
—Leach Corp., Controls Div., Los Angeles, Calif.

Circle No. 329 on reply card

PLUS . . .

(330) A series of **silicon controlled switches** capable of switching from 1 to 200 ma has been made available by **Transitron Electronic Corp.**, Wakefield, Mass. . . . (331) The first non-electric, self-powered **engine safety control system** to protect all engine installations against dangerous overspeed, temperature, and pressure conditions is now on the market from **California Controls Co.**, Oakland, Calif. . . . (332) **Industrial Timer Corp.**, Newark, N. J., has developed a 12-position adjustable **rotary selector switch** that is designed for rapid program changes and has 10-amp contact rating on each circuit.

Circle Nos. 330, 331, or 332 on reply card



REMOTE CONTROLLER

This new instrument provides remote open-stop-close or on-off control and status indication of power operated devices. Both the control and indication for valves, motors, blowers, pumps, and other such devices can be accomplished with only two wires between the remote point and the control location. The front cover of the unit is designed to carry a graphic symbol for use on graphic display boards. Maximum loop line resistance may be as high as 100 ohms for incandescent indicators and 2,000 ohms for neon indicators. Standard field unit is suitable for controlling up to 2-amp coils at 480 volts, and larger capacities are available.—Texas Instruments, Inc., Geosciences & Instrumentation Div., Houston, Tex.

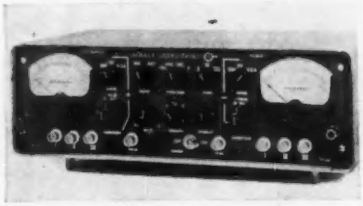
Circle No. 333 on reply card

POWER SUPPLIES

PORTABLE POWER

Intended as a component of automatic systems for remote programming and bench use, this portable transistorized power supply is rated at 0-12 vdc, 0-2.5 amps, continuously variable. Both line and load regulation are to within 0.05 percent; overshoot is less than 1 percent of voltage setting with 50-microsec recovery time; ripple is 250 microvolts max. Just 6 x 8 x 10 in., the unit sells for $295.—Mid-Eastern Electronics, Inc., Springfield, N. J.

Circle No. 334 on reply card



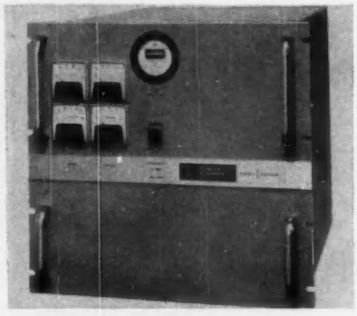
TUNNEL DIODE SUPPLY

A unique pulsing power supply that provides pulsed outputs in a variety

NEW PRODUCTS

of pulse and regulated combinations is intended for programming tunnel diode or parametron logic networks in addition to general power use. Six pulsed outputs may be selected, consisting of three overlapping pulses and their complements. But any combination of pulses, with or without superimposition on a regulated dc voltage, may be obtained. Pulses are phase locked to either an external or internal clock variable from 500 kcps to 2 Mcps.—Strazsa Industries, Electronics Div., El Cajon, Calif.

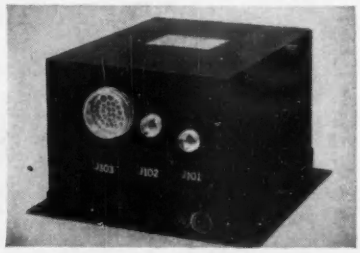
Circle No. 335 on reply card



SINE WAVE SUPPLY

A new high power sine wave supply uses a unique circuit so that it cannot be damaged by overload, short circuits, or open circuits. No fuses, relays, or cutouts are used. An input of 105-125 vdc is needed to produce a nominal output of 117 volts and 1,000 va power. Frequency is 60 cps ±1 percent with 70 percent minimum efficiency. Line regulation is to within better than 6 percent; load regulation, better than 5 percent. The unit fits standard 19-in. racks, taking up 17½ in.; weight is 180 lb.—Power Sources, Inc., Burlington, Mass.

Circle No. 336 on reply card



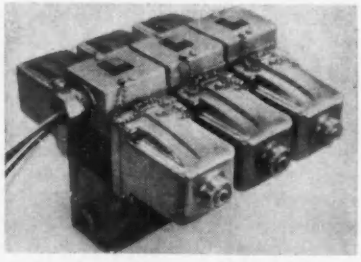
HIGH VOLTAGE, LOW WEIGHT

Dc power of 10,000 volts is available from a new supply that weighs only 5¾ lb. Designed specifically to provide the gun potential to a high per-

sistency display tube, the power unit may be used in other applications where space and weight are prime factors. The device, hermetically sealed, is of the unregulated transformer-rectifier type and operates from an input of 115 volts, 400 cps. The output is fixed at 10,000 vdc, 2 ma with ripple of less than 20 volts peak to peak. Dimensions: $4\frac{1}{2}$ x $5\frac{3}{4}$ x $6\frac{3}{4}$ in. —Industrial Products Div., International Telephone and Telegraph Corp., San Fernando, Calif.

Circle No. 337 on reply card

ACTUATORS & FINAL CONTROL ELEMENTS



DIRECT ACTING VALVES

Designed for manifold mounting, a new line of $\frac{3}{8}$-in. high performance direct acting solenoid valves is available in models for positive pressure air, vacuum, or all conventional hydraulic fluids. Up to five valves can be mounted on a manifold on $2\frac{3}{8}$-in. centers. The line is available as double solenoid, single solenoid, or spring return types; 2, 3, or 4-way; and 2 or 3-position. Electrical junction box is built in.—The Beckett-Harcum Co., Wilmington, Ohio.

Circle No. 338 on reply card

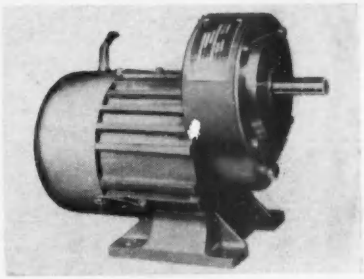
SYNCHRONOUS DRIVES

Ranging in size from 2 to 15 hp, a new line of Syncro-Range drives provides adjustable speed of synchronous induction motors running in exact synchronism over a wide speed range. The drive is an integrated system consisting of an adjustable frequency power supply, one or more Syncro-Spede drive motors, and a control panel. The adjustable frequency power is supplied

NEW PRODUCTS

from an ac alternator driven by a constant speed squirrel cage induction motor which provides infinitely adjustable speed through a system of adjustable discs and a ribbed belt. The control panel provides an alternator field supply and all necessary controls for operation of the drive.—The Louis Allis Co., Milwaukee, Wis.

Circle No. 339 on reply card



EXPLOSION-PROOF

A new explosion-proof induction motor has been added to this manufacturer's line of miniature and subminiature motors. Manufactured by a wholly owned subsidiary, Hertner Electric Co., the DEF-15-1 was designed for the ground handling system of the La Crosse missile, but its high starting torque makes it suitable for a variety of uses. The ½-hp motor runs on 200/400 volts at 400 cps, turns at 1,490 rpm with 14.2 lb-in. full load torque and 71.25 lb-in. starting torque. The unit weighs 11 lb.—Kearfott Div., General Precision, Inc., Little Falls, N. J.

Circle No. 340 on reply card

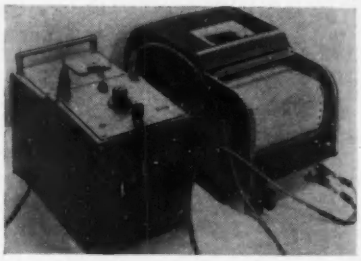
LIGHTEST DRIVE

Described by its manufacturer as the most compact and lightest fractional horsepower variable speed drive available, the new Speed-Trol is said to have the shortest over-all dimensions and to be 15 percent lighter than com-

petitive units. Speed ranges are from 4,660 to 1.2 rpm with up to 10 to 1 variation in ¼, ½, and ¾-hp ratings. Standard NEMA dimensions for shaft height and diameter permit interchange with standard motors.—Sterling Electric Motors, Los Angeles, Calif.

Circle No. 341 on reply card

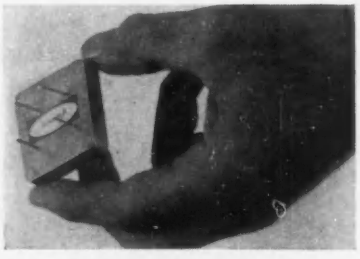
COMPONENT PARTS



HIGH GAIN PREAMP

Shown above driving a recorder, the VS-67A dc amplifier provides high gain preamplification with enough output power to perform tasks like that above and still have good input sensitivity. Gain is 10-80 db steps, frequency response is 0-3 cps (−3db), and linearity is within 0.5 percent at 0-100 and 1.5 percent at 0-250 microvolts dc input. Maximum output is ±2.5 volts, ±1 ma. Noise referred to shorted input is 1 microvolt rms max.—Millivac Instruments, Div., Cohu Electronics, Inc., Schenectady, N. Y.

Circle No. 342 on reply card



FOR PRINTED CIRCUITS

Specially designed for printed circuit board insertion, these miniaturized voltage reference standards have a temperature coefficient of ±0.0005 percent per deg C from zero through +60 deg C. They operate directly from an unregulated dc power source and have output voltages of 5.8, 8.5, or 10.5 vdc ±5 percent with regulation to ±0.005 percent for dc input variation of ±10 percent. Dimensions

NEW PRODUCTS

are 1 7/16 in. square by 3/8 in. thick; leads are designed for mounting on boards with standard 1/2-in. spacing. Price: $60.—Viking Industries, Inc., Canoga Park, California

Circle No. 343 on reply card

INEXPENSIVE D-A CONVERTER

The BDA-6 is an inexpensive, accurate digital to analog converter available as a standard plug-in etched module. Each module contains six stages and can be used as a six-bit converter. Two identical modules can be connected to form a 12-bit converter with accuracy to within 0.1 percent. Settling time for a full scale voltage change of 10 volts is 2 microsec. Output impedance is 2,250 ohms. Price: $275 per module.—Abacus, Inc., Los Angeles, Calif.

Circle No. 344 on reply card

PLUS . . .

(345) High efficiency **miniature magnetic clutches** with minimum torque rating of 10 oz-in. at speeds to 1,000 rpm are now being produced by **Ultronix, Inc.**, San Mateo, Calif. . . . (346) **General Electronic Control, Inc.**, Minneapolis, Minn., has brought out a line of solid state modular **SCR phase controllers and servoamplifiers** with 1/2-cycle max response time. . . . (347) The availability of four new **trigger tubes**—for high and low current applications—said to be the smallest on the market of this type has been announced by **Signalite, Inc.**, Neptune, N. J.

Circle Nos. 345, 346, or 347 on reply card

ACCESSORIES & MATERIALS

GOLD FOR SEMICONDUCTORS

Gold 99.99+ percent pure alloyed with antimony, silicon, germanium, gallium, or tin and fabricated into spheres, foil, washers, discs, rectangles, and squares for semiconductor devices has now been made available. Sphere sizes range from 0.005 with tolerances as close as 0.0001 in. Discs are made from 0.005 in., foil is available 0.0005 in. thick, rectangles are from 0.040 to 0.015 in., squares are 0.020 in., and

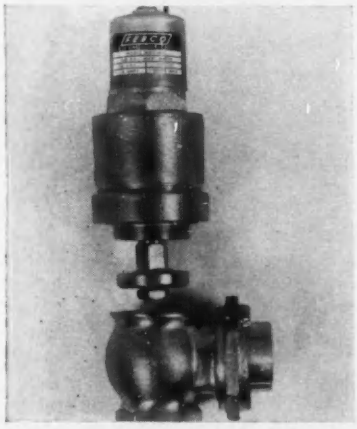
washers are made from 0.020 ID with land of 0.005 in.–Alpha Metals, Inc., Jersey City, N.J.

Circle No. 348 on reply card

WINDS AUTOMATICALLY

Winding paper tape is made a simple, unattended operation with a low cost portable tape winder now being produced. The winder is designed for storing transmitted tape in teletypesetting, data processing, automatic letter typing, etc. The winder's 12-in. metal reel holds up to 1,300 ft of chadless tape and up to 2,000 ft of fully perforated tape. Winding tension is adjustable for maximum tightness without tearing tape. The device is 16⅜ in. high, 12½ in. wide, and 6 in. deep; it weighs 13½ lb.–Western Apparatus Co., Div. of Comptometer Corp., Chicago, Ill.

Circle No. 349 on reply card



MAKES VALVES AUTOMATIC

Manually operated valves are easily made automatic using a new adapter that works with present piping and valve bodies so that lines need not be disturbed. Installation is made by removing the valve stem and bonnet of the valve and screwing the adaptor in their place. The adaptor is then linked by wiring or hydraulic tubing to a switch. Models are available for most standard globe valves now in use and will cost about $20-30.–Febco, Inc., Los Angeles, Calif.

Circle No. 350 on reply card

SYSTEMS

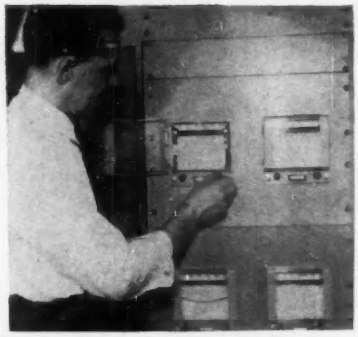
STEP BY STEP

A new system, called STEP–Simple Transition to Electronic Processing–

NEW PRODUCTS

has been developed to bring electronic data processing to small businesses. It is designed for firms now using punched card equipment. Units comprising STEP are a central data processor with 26,000-digit capacity, high speed reader (450 cards per min) punch (150 cards per min), and a high speed printer. Monthly rental: $3,500.–Remington Rand Univac Div., Sperry Rand Corp., New York, N. Y.

Circle No. 351 on reply card



MINIATURE CONTROLLER

The M-Line temperature control loop is a system that provides all of the required instrumentation to measure and control a furnace. Instruments used are a temperature transmitter; single-pen recorder; control system using a controller, setpoint unit, and auto-manual station; and a magnetic amplifier. While the system provides maximum flexibility in operation with provisions for integrating data handling and computing equipment, all the components are based on a miniature design concept and consist of modern plug-in units. – Leeds & Northrup Co., Philadelphia, Pa.

Circle No. 352 on reply card

SOLID STATE SCANNERS

The B-1000 series of electronic scanning systems provides extremely reliable continuous scanning of functions, using no relays, stepping switches, or motor driven commutators or rotating switches. They perform monitoring, alarming, and remote station on-off control functions from a central station for completely unattended operation of power substations, pumping plants, pipeline installations, etc.–Lynch Communication Systems, Inc., San Francisco, Calif.

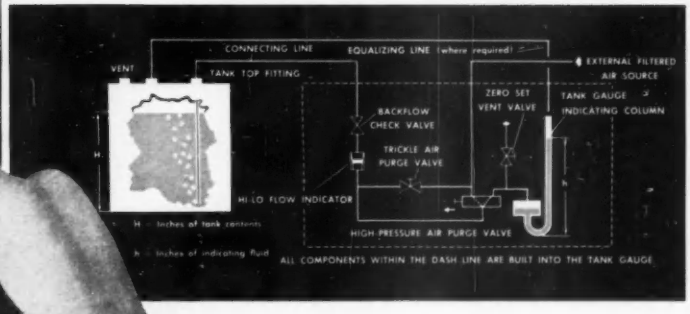
Circle No. 353 on reply card

integral blow-down TANK GAUGE

FOR CONTINUOUS PURGING SYSTEMS

Now . . . FOR THE FIRST TIME . . . you can specify a continuous purge tank gauge and blow-down device *with all the working parts in one package!* It's easy to clean out tank gauging lines with this scavenging method that is completely independent of the normal tank gauge operation. Just pull one knob to remove condensate, scale and sludge from your tank gauging lines connected to either vented or pressurized closed tanks. And . . . there's no need for extraneous plumbing! Meriam's new tank gauge requires only two connections to your present system. In hazardous areas, the instrument may be located up to 800 feet from the tank, depending on the filling and emptying cycle. Gauges are available in single or dual blow-down units and in compact multiple-tube groups with up to six gauging tubes in one assembly. Send for complete specifications and operating instructions today.

HERE'S HOW THE MERIAM HYDROSTATIC GAUGING SYSTEM WORKS



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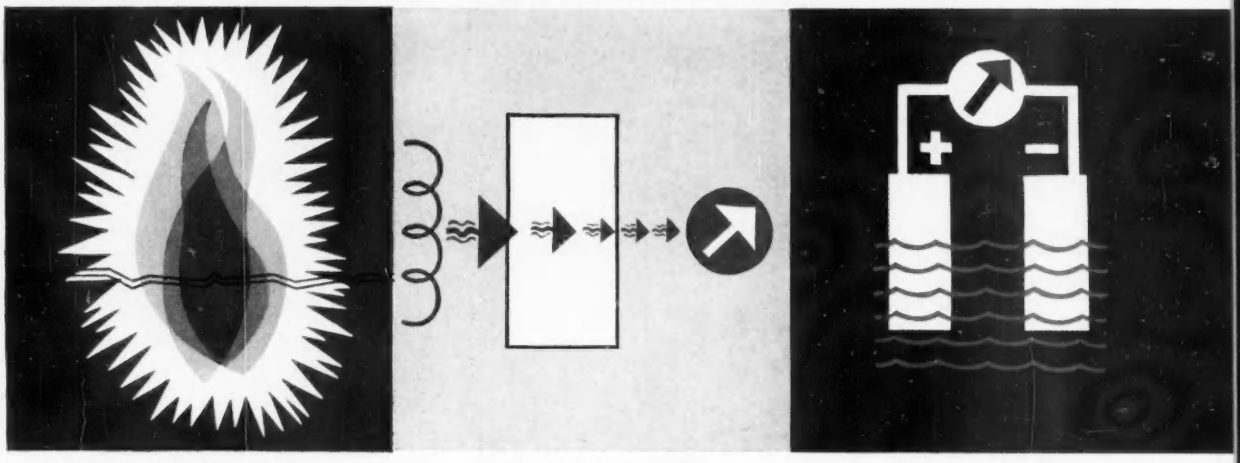
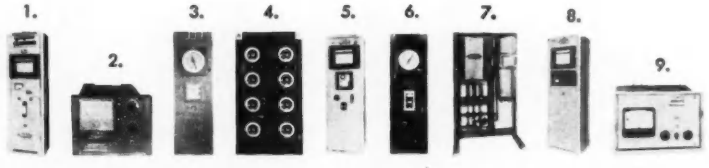


Catalytic Combustion | Infrared Analysis | Depolarization

INSTRUMENT DIVISION
Mine Safety Appliances Company
Pittsburgh 8, Pennsylvania



1. M-S-A® LIRA® Infrared Analyzer Model 200 **2.** M-S-A® LIRA® Infrared Analyzer Model 300 **3.** M-S-A® Inert Gas Analyzer **4.** M-S-A® Combustible Gas Analyzer **5.** M-S-A® Thermatron Analyzer **6.** M-S-A® Oxygen Indicator **7.** M-S-A® Water Vapor Recorder **8.** M-S-A® BillionAire* Analyzer **9.** M-S-A® Process Refractometer

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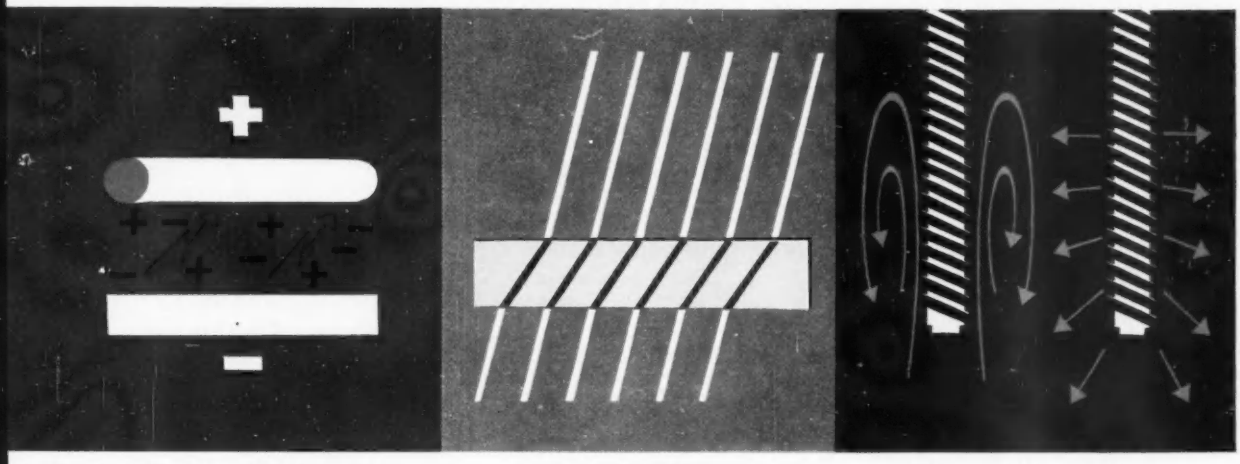
for dependable process stream analysis



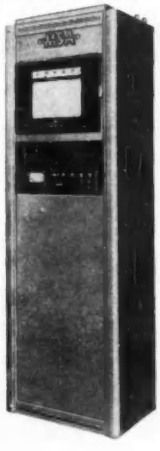
Refraction **Thermal Properties**

Ionization: Now MSA simplifies control of contaminants in the parts per *billion* to parts per million range. The new M-S-A® BillionAire* Analyzer is the hypersensitive instrument.

It's already at work in air pollution studies, process monitoring and continuous measurement of toxic gases in air.

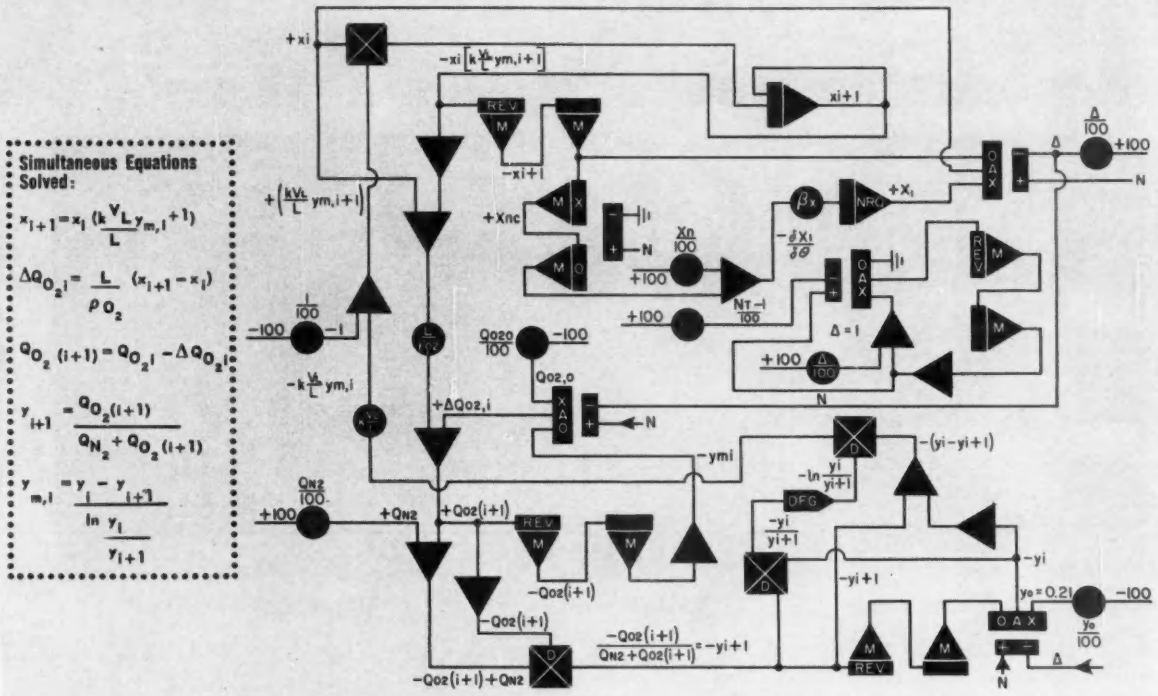
Except when measuring oxygen in low concentrations, the instrument is sensitized for a specific problem by reacting the gas of interest with a reagent system to convert that gas to an aerosol. The aerosol passing through the ionization chamber changes its electrical conductivity which unbalances a bridge circuit in proportion to concentration. This in turn is indicated by an integral meter or recorder.

This same brand of instrument ingenuity is evident in all of the other techniques applied by Mine Safety Appliances Company. The versatility of these techniques is symbolized in the illustrative panel above.



One or more of these approaches could help you. Let's talk about your process problem. Invite an MSA Instrument Specialist to call. And write for new M-S-A BillionAire Analyzer bulletin or any of our other process stream analyzer literature.

Diagram for determining outlet concentration of a counter current multi-stage oxidizer



Multi-Stage Oxidation Problems Solved in Seconds with DYSTAC Computer!

Dynamic memory and high-speed repetitive operation exclusive with DYSTAC analog computers offer the simplest, most accurate, lowest-cost way of solving multi-stage oxidizer problems. Now, with DYSTAC, any desired specifications can be selected for a given problem. Solutions are achieved at a continuous frequency of 60 cycles per second with an accuracy of ±0.1%. Size of DYSTAC is independent of the number of stages since its dynamic memory permits time sharing of computing elements. Its solution time for a given set of operating conditions is only a few seconds for 10 stages.

Whether your problems are dynamic or static, covering costs, design or production control in: Operations Research, Chemical Kinetics, Structures or Hydrodynamics, DYSTAC can solve them faster, more accurately and more economically than any other computer.

A computer is judged by the problems it solves. Here are some problems which DYSTAC will solve in 20 seconds.

- multi-dimensional partial differentials (steady state or transient)
- sequential, successive solutions for algebraic matrices at 60 to 100 cps
- definite integral calculations
- multiple integrals and partial differential equations . . . or any combination of these problems

Send for detailed report "Counter Current Multi-Stage Oxidation." Learn how DYSTAC *cuts time and costs in solving complex problems that up to now defied either analog or digital computer solution.*

COMPUTER SYSTEMS, INC., Culver Road, Monmouth Junction, N. J. • DAvis 9-2351

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4	18	32	46	60	74	88	102	116	130	144	158	172	186	200	214	228	242	256	270	284	298
5	19	33	47	61	75	89	103	117	131	145	159	173	187	201	215	229	243	257	271	285	299
6	20	34	48	62	76	90	104	118	132	146	160	174	188	202	216	230	244	258	272	286	300
7	21	35	49	63	77	91	105	119	133	147	161	175	189	203	217	231	245	259	273	287	301
8	22	36	50	64	78	92	106	120	134	148	162	176	190	204	218	232	246	260	274	288	302
9	23	37	51	65	79	93	107	121	135	149	163	177	191	205	219	233	247	261	275	289	303
10	24	38	52	66	80	94	108	122	136	150	164	178	192	206	220	234	248	262	276	290	304
11	25	39	53	67	81	95	109	123	137	151	165	179	193	207	221	235	249	263	277	291	305
12	26	40	54	68	82	96	110	124	138	152	166	180	194	208	222	236	250	264	278	292	306
13	27	41	55	69	83	97	111	125	139	153	167	181	195	209	223	237	251	265	279	293	307
14	28	42	56	70	84	98	112	126	140	154	168	182	196	210	224	238	252	266	280	294	308

NEW PRODUCTS & BULLETINS **REPRINTS**

309	320	331	342	353	364	375	386	397	408	419	430	441	452	463	474	485	496	507
310	321	332	343	354	365	376	387	398	409	420	431	442	453	464	475	486	497	508
311	322	333	344	355	366	377	388	399	410	421	432	443	454	465	476	487	498	509
312	323	334	345	356	367	378	389	400	411	422	433	444	455	466	477	488	499	510
313	324	335	346	357	368	379	390	401	412	423	434	445	456	467	478	489	500	511
314	325	336	347	358	369	380	391	402	413	424	435	446	457	468	479	490	501	512
315	326	337	348	359	370	381	392	403	414	425	436	447	458	469	480	491	502	513
316	327	338	349	360	371	382	393	404	415	426	437	448	459	470	481	492	503	514
317	328	339	350	361	372	383	394	405	416	427	438	449	460	471	482	493	504	515
318	329	340	351	352	373	384	395	406	417	428	439	450	461	472	483	494	505	516
319	330	341	352	363	374	385	396	407	418	429	440	451	462	473	484	495	506	517

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Index of advertised equipment, new products, and bulletins. For additional information circle number on card corresponding to number to left of item.

1. SYSTEMS

Advertisements

2—Solid-state missile checkout, p. 2
13—Electronic process controls, p 12
20—Thrust control system, p. 20
23—Engineered data systems, p. 22
25—Control system planning, p. 24
71—Ultrasonic detection system, p. 71
172—Monitor-alarm system designed for process industry needs, p. 172
184—Systems and components for positioning applications, p. 184
185—Hydrostatic gaging system, p. 185
204—Infrared control system, p. 204
214—Custom system and panel work, p. 214

New Products

351—Data processing system designed for small businesses, p. 184
352—Furnace temperature system, p. 184
353—Electronic scanning systems, p. 184

Catalogs and Bulletins

401—Data handling system at work, p. 194
410—Extruder measurement problems, p. 195
422—Materials handling systems, p. 196
426—Density control system, p. 196
428—Development of automation, p. 197

2. DATA HANDLING AND DISPLAY EQUIPMENT

Advertisements

6—Memory drum line, p. 6
7—Direct writing recorders, p. 7
11—Simple-to-use scopes, p. 11
21—Magnetic disc memory, p. 21
26—Fast response tape unit, p. 26
36—Punched tape equipment, p. 36
46—Easy loading oscillograph, p. 46
47—Writes 50,000 ips, p. 47
51—Added page printer control, p. 51
54—Binary to decimal display, p. 54
57—Solid state tape recorder, p. 57
59—Versatile digital voltmeter, p. 59
76—Flexible recorder design, p 76
134—Random access memory, p. 134
148—Fine trace, 8-channel direct writing recorder, p. 148
160—Industrial annunciator line, p. 160
162—Simpler computer operation, p. 162
167—High-speed events recorder, p. 167
177—Small multipoint recorder, p. 177
183—Perforated tape reader, p. 183
193—High speed printers, p. 193
195—Versatile desk calculator, p. 195
197—Compact digital display, p. 197
201—Digital readout applications, p. 201
221—Miniature millivolt recorder, p. 221
225—Packaged airborne computers, 2nd cover
232—High speed card reader, p. 214
240—In-line digital readouts, p. 220

New Products

310—Digital telemetering system, p. 165
311—Linear count rate meter, p. 166
312—Versatile tape converter, p. 166
313—Decade counting tubes, p. 166
314—A/D and D/A converter lines, p. 166
315—High-speed x-y plotter, p. 166

Catalogs and Bulletins

400—Computer application data, p. 194
406—Shift register theory, p. 194
420—Film on memory devices, p. 196

3. RESEARCH, TEST, AND DEVELOPMENT EQUIPMENT

Advertisements

5—Frequency period meter, p. 5
63—Universal servo analyzer, p. 63
85—Portable level system, p 85
94—Fast analog computation, p. 94
102—Versatile analog computer, p. 102
187—Stream analyzer line, p. 186
188—Typical computer problem, p. 188
205—Compact analog computer provides Bode phase and gain plots, p. 205
223—Pulse waveform generator, p. 223
236—Precision autocollimator, p. 217

New Products

316—Universal ac potentiometer, p. 169
317—Expanded scale voltmeters, p. 169
318—New CRT for oscilloscopes, p. 170
319—System checkout unit, p. 170
320—Electronic system analyzers, p. 172

Catalogs and Bulletins

404—Pulse generator applications, p. 194
408—Adsorption phenomena described, p. 194
419—Chromatograph application, p. 196
433—Precision test instruments, p. 197

4. PRIMARY ELEMENTS AND TRANSDUCERS

Advertisements

18—Dual bellows meter body, p. 18
28—Indicating magnetic flowmeter, p. 28
40—Direct reading strain gages, p. 40
49—Non-ambiguous encoders, p. 49
77—Submarine periscope system, p. 77
81—New A/D converter handles five million samples per sec, p 81
84—Corporate name change for flow instrument manufacturer, p. 84
89—Complete manometer line, p. 89
101—Motion-balance transmitter, p. 100
154—Magnetic flowmeter applied, p. 154
166—Foul-proof pressure transmitter, p. 166

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3	17	31	45	59	73	87	101	115	129	143	157	171	185	199	213	227	241	255	269	283	297
4	18	32	46	60	74	88	102	116	130	144	158	172	186	200	214	228	242	256	270	284	298
5	19	33	47	61	75	89	103	117	131	145	159	173	187	201	215	229	243	257	271	285	299
6	20	34	48	62	76	90	104	118	132	146	160	174	188	202	216	230	244	258	272	286	300
7	21	35	49	63	77	91	105	119	133	147	161	175	189	203	217	231	245	259	273	287	301
8	22	36	50	64	78	92	106	120	134	148	162	176	190	204	218	232	246	260	274	288	302
9	23	37	51	65	79	93	107	121	135	149	163	177	191	205	219	233	247	261	275	289	303
10	24	38	52	66	80	94	108	122	136	150	164	178	192	206	220	234	248	262	276	290	304
11	25	39	53	67	81	95	109	123	137	151	165	179	193	207	221	235	249	263	277	291	305
12	26	40	54	68	82	96	110	124	138	152	166	180	194	208	222	236	250	264	278	292	306
13	27	41	55	69	83	97	111	125	139	153	167	181	195	209	223	237	251	265	279	293	307
14	28	42	56	70	84	98	112	126	140	154	168	182	196	210	224	238	252	266	280	294	308

NEW PRODUCTS & BULLETINS

309	320	331	342	353	364	375	386	397	408	419	430	441	452	463
310	321	332	343	354	365	376	387	398	409	420	431	442	453	464
311	322	333	344	355	366	377	388	399	410	421	432	443	454	465
312	323	334	345	356	367	378	389	400	411	422	433	444	455	466
313	324	335	346	357	368	379	390	401	412	423	434	445	456	467
314	325	336	347	358	369	380	391	402	413	424	435	446	457	468
315	326	337	348	359	370	381	392	403	414	425	436	447	458	469
316	327	338	349	360	371	382	393	404	415	426	437	448	459	470
317	328	339	350	361	372	383	394	405	416	427	438	449	460	471
318	329	340	351	352	373	384	395	406	417	428	439	450	461	472
319	330	341	352	363	374	385	396	407	418	429	440	451	462	473

REPRINTS

474	485	496	507
475	486	497	508
476	487	498	509
477	488	499	510
478	489	500	511
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484	495	506	517

Name _____ *Title* _____

Company _____

Address _____ *City* _____ *Zone* _____ *State* _____

7. ACTUATORS AND FINAL CONTROL ELEMENTS

(Continued on page 193)

ADVERTISEMENTS — *Mail Before February 1, 1961*

1	15	29	43	57	71	85	99	113	127	141	155	169	183	197	211	225	239	253	267	281	295
2	16	30	44	58	72	86	100	114	128	142	156	170	184	198	212	226	240	254	268	282	296
3	17	31	45	59	73	87	101	115	129	143	157	171	185	199	213	227	241	255	269	283	297
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476	487	498	509
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478	489	500	511
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480	491	502	513
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483	494	505	516
484	495	506	517

Name _____ *Title* _____

Company _____

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488—A Roundup of Control System Test Equipment, 60 cents
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486—A New Way to Select the Best Control Valve, 50 cents
485—Fundamentals of Tie-Motor Control, 30 cents
484—How to Use Phase-Plane Techniques, 50 cents
483—Economics in Control, 50 cents
482—Static Switching Devices, 50 cents
480—Applying Control Timers, 50 cents
478—Servo Modulators, 65 cents
477—Basic Data on Process Control Systems, 50 cents
476—Three Ways to Simulate Dead Time, 15 cents

Equipment Index

(Continued from page 191)

8. COMPONENT PARTS

Advertisements

New Products

Catalogs and Bulletins

9. ACCESSORIES AND MATERIALS

Advertisements

New Products

Catalogs and Bulletins

BULLETINS AND CATALOGS

(400) COMPUTER APPLIED. Computer Div., Bendix Corp. Application report. Covers applications of the company's G-15 digital computer in highly diversified companies and mechanical engineering firms. Installations described represent some of the many successful methods of using computers for mechanical engineering work.

(401) DATA HANDLING SYSTEM. Leeds & Northrup Co. Application Data Sheet N-7(2), 4 pp. Shows how a new 600-channel sequential data handling system is now being used to monitor the bearing, boiler tube, and condensate temperatures of a 290-Mw boiler turbine-generator unit. Explains the operations of the complete system, including both logging and alarm units.

(402) SUPERVISORY CONTROLS. General Electric Co. Bulletin GEZ-3078, 12 pp. Describes the company's new supervisory instrumentation for use with industrial turbines. Also includes details on the system's ability to monitor vibration, shaft eccentricity, shell and differential expansion, speed and valve positions.

(403) TRANSDUCER CATALOG. Statham Instruments, Inc. General Catalog, 32 pp. Provides concise descriptions of Statham pressure transducers, linear and angular accelerometers, load cells, amplifiers, power supplies, bridge balances, strain gages, and force/displacement transducers. Easy-to-read selection charts keyed to instrument ranges facilitate equipment selection for specific user requirements.

(404) PULSE GENERATOR DATA. Valor Instruments, Inc. Booklet, 12 pp. Describes typical applications of pulse generators with particular emphasis on high speed transistorized circuits. Also explains the features, advantages, and limitations of a new solid-state pulse generator designed for use with transistorized circuitry.

(405) STEPPING SWITCHES. C. P. Clare & Co. Catalog 202, 40 pp. Covers Clare's complete line of spring-driven, cam operated, and direct drive stepping switches. Construction features, circuitry, and performance characteristics are thoroughly discussed.

(406) WIDE-WIDTH SHIFT REGISTERS. Magnetics Research Co. Engineering bulletin, 4 pp. Includes informative technical discussion of "wide-width" theory, as well as circuit diagrams explaining the function of a unique data control circuit which reduces equipment requirements to one core per bit.

(407) COMPUTING RESOLVERS. Theta Instrument Corp. Illustrated monograph, 16 pp. Reviews the characteristics of computer resolvers, defines important properties such as function error and axis error, and describes basic measurement techniques.

(408) SURFACE AREA MEASUREMENT. Perkin-Elmer Corp. Specification sheet, 4 pp. Describes the company's Model 212 Sorptometer, an instrument designed for rapid, accurate measurement of surface areas of solids and other adsorption phenomena. Covers operation, con-

struction, theory, and specifications.

(409) GAGE PRESSURE PICKUP. Instrument Div., Bourns, Inc. Bulletin No. 3041/G/O, 2 pp. Contains the latest information on a new Model 304 gage pressure transducer, a unit which incorporates a Bourdon tube as the pressure sensing element. Also includes a table of specifications and dimension drawings.

(410) EXTRUDER MEASUREMENT. Industrial Nucleonics Corp. Brochure PL-560, 12 pp. Deals with the methods of measuring and automatically controlling the three significant thickness variables of extruded plastic materials: long term machine direction variations, short term machine direction variations, and profile variations. Further describes AccuRay measurement and control systems designed to minimize these variations, thereby increasing yield and uniformity.

(411) SEMICONDUCTOR PRODUCTS. Motorola Semiconductor Products, Inc. Brochure, 12 pp. Attractive four-color brochure describes the company's complete line of industrial and military semiconductor products. Lists key specifications on germanium power transistors, audio and switching transistors, silicon and germanium mesa transistors, silicon rectifiers, and zener diodes.

(412) SUPER ALLOY TUBE. Superior Tube Co. Bulletin No. 71, 16 pp. Using text, tables, graphs, and photographs, this 16-page bulletin serves as a short educational course on super alloy tubing. It explains how its resistance to high temperature makes the tubing a valuable engineering material in aircraft and missile design and has led to its use in such typical applications as hot gas generators, hot gas ducts, engine parts, and hydraulic lines of all kinds.

(413) PRESSURE GAGES. U. S. Gauge, Div. of American Machine & Metals, Inc. Bulletin 3020, 6 pp. Illustrates typical examples from a complete product line. These include pressure gages, test gages, thermometers, and controllers.

(414) NEW SYNCHRONOUS MOTORS. The Superior Electric Co. Folder SE-L2604, 8 pp. Contains technical characteristics, specifications, ratings, and outline dimensions of four new Slo-Syn synchronous motors. Torque ratings include 50, 150, and 250 oz-in.

(415) HYDRAULIC PRODUCTS. Vickers, Inc. Div. of Sperry Rand Corp. Catalog 5001C, 74 pp. Covers both new and standard lines of hydraulic products for the industrial, marine, and ordnance fields. Equipment lineup includes: power packages, servovalves, servosystems, vane piston pumps, pressure flow and directional controls, control assemblies, hydraulic motors, variable speed drives, and hydraulic cylinders.

(416) TEMPERATURE PROBES. Rosemount Engineering Co. Catalog No. 66030, 8 pp. Illustrated two-color booklet contains specifications and descriptions on a number of precise platinum temperature transducers, pressure transducers, pitot-static tubes, and signal conditioning and accessory equipment. Temperature probes cataloged include 36 different aerodynamic immersion and surface types.

(417) ANGULAR ACCELEROMETERS. Donner Scientific Co., Sub. of

Bulletins & Catalogs

Systron Donner Corp. Folder, 6 pp. Covers features, operation, application, and specifications dealing in the company's Model 4525 angular servo accelerometer, in both liquid and gas-filled configurations. Illustrations include photos, outline drawings, and a single operational diagram.

(418) ELECTRICAL CONNECTORS. The Superior Electric Co. Bulletin PR259-1, 12 pp. Includes technical information, ratings, and over-all dimensions on a new line of single conductor plugs and receptacles. Printed in four colors, bulletin describes all 25, 50, 100, and 250-amp types offered.

(419) APPLIED CHROMATOGRAPHY. Beckman Instruments, Inc. Application Data Sheet GC-8067-F, 2 pp. Describes the use of a Beckman GC-2 gas chromatograph in the analysis of flavor components in beer. Tells how the analyzer tracks changes in volatiles which are continually taking place during the beer-making cycle.

(420) FILM ON MEMORIES. Bell Telephone Laboratories, Inc. Booklet, 24 pp. Describes a 27-min sound-color motion picture on memory devices. This 16-mm film, aimed at science and engineering groups, covers fundamental concepts and eleven different types of machine memories.

(421) VALVE OPERATOR. Philadelphia Gear Corp. Bulletin 7A-60, 8 pp. Deals with the construction and performance of a new "G" Series gas operator, an oscillating vane-type hydraulic motor designed for use on plug valves in gas pipelines.

(422) MINING EQUIPMENT. Fuller Co. Bulletin G-11, 4 pp. Pictures and describes equipment designed to increase automation in the nonmetallic mining and manufacturing industries. Bulletin summarizes the capabilities of the company's pneumatic conveyors, compressors, pumps, blowers, coolers, preheaters, control panel, level indicators, and other equipment.

(423) QUALITY TUBING. Superior Tube Co. Bulletin No. 372, 12 pp. Presents details on the features of the company's line of small diameter metal tubing for fluid handling lines, engine applications, aircraft and missile instrument applications, and for airframe application. Handy table lists results of tests on various types of hydraulic and fuel line tubing.

(424) MOTOR SELECTION. General Electric Co. Form GED-3909A. This handy 3 x 7 in. pocket-size card provides a quick reference to frame size and book price for ac motors from ¾ to 125 hp. Covers both drip-proof and totally enclosed fan-cooled squirrel cage motors.

(425) LOW-COST CLUTCH. Vickers, Inc. Bulletin EPD 6106-5, 4 pp. Offers details on the construction and operation of a new dry magnetic particle clutch having a rated output of 10 lb-ft. Other information includes dimensions, specifications, performance curves, and schematic of a simple electrical control.

(426) SLUDGE DENSITY CONTROL. The Ohmart Corp. Bulletin SD-1, 2 pp.

Explains how the density of sludge in sewage treatment plants is automatically controlled. Illustrations include a schematic showing a positive density control system for sludge pumping and another showing the components of a density meter system.

(427) ELECTRIC CONTROLLER. Minneapolis-Honeywell Regulator Co. Specification FS-301-9, 6 pp. Describes Honeywell's new ElectriK Tel-O-Set indicators and indicating control stations for the continuous indication and recording of standard 4-20 made output signals. Controller specifications, dimensions, and special features are included.

(428) UTILITY AUTOMATION. General Electric Co. Publication GEA-7044, 24 pp. Contains information concerning the 50-year development of automated equipment and systems for electric utilities. Bulletin describes all phases of system operation and traces the utilities' use of automated equipment back to the unattended rotary converter stations used for street railways in 1910.

(429) SEALED SWITCHES. Control Switch Div., Controls Co. of America. Catalog No. 130, 18 pp. Contains complete engineering and technical details on all of the company's hermetically-sealed and environment-free switches. One section shows how modular construction permits the selection of actuator, termination, housing, and operating characteristics that best suit a particular need.

(430) THERMOCOUPLE GUIDE. The Bristol Co. Bulletin T1238, 56 pp. A new edition of Bristol's "Buyers' Guide and Users' Manual", covering thermocouples and pyrometer accessories, is now available. Divided into three sections, bulletin outlines possible applications for the company's pyrometer accessories, catalogs specifications covering this equipment, and contains eight full pages of thermocouple calibration data.

(431) GEAR SPECS. PIC Design Corp. Technical booklet No. 5, 32 pp. Covers specifications and standards for low-energy, custom made certified military-type fine-pitch spur gears. Specification section outlines military inspection, manufacturing, and quality control specifications.

(432) ELECTRONIC HARDWARE. Lerco Electronics Inc. Catalog 32, 32 pp. Contains complete specifications and ordering information for standard and insulated terminals; terminal boards; eyelets, stand-offs, shaft locks, and miscellaneous hardware; handles and control knobs; and custom engineered products.

(433) TEST EQUIPMENT. Precision Apparatus Co., Inc. and Pace Electrical Instruments Co., Inc. Catalog No. 28, 20 pp. Issued jointly by these two companies, catalog describes Precision's line of electronic test equipment and Pace's panel meters for industrial and communications applications. Details include both electrical and mechanical specifications.

(434) FUEL CELL OPERATION. Pratt & Whitney Aircraft Div. of United Aircraft Corp. Brochure, 12 pp. Contains a compact description of the operation and application of fuel cells, electrolytic cells in which the chemical energy of basic fuels is converted directly into electric current.

WHAT'S NEW

(Continued from page 54)

esting complex wiring, and Numill, a numerical control for positioning and path control of machine tools.

A recent spurt in sales of RECOMP II has boosted sales of this unit to well over 30 in the highly competitive small computer field. Installations of the computer vary widely, a most unusual one being a computing-control stint at Phillips Petroleum's ethylene plant in Sweeney, Tex., where Autonetics joined with Phillips in an experimental control program (CtE, Sept. '60, p. 150).

A 10-percent increase in ethylene production resulted from using the computer first for process analysis and testing to develop the best way to run a thermal cracking furnace. Employing this data, just a few month's production paid for the entire experimental effort. Plans call for further use of RECOMP II to evaluate computer control for petroleum and chemical processes.

• **Scandinavian cooperation**—An important aid to NAA's hopes for RECOMP II came with an agreement concluded by the Industrial Products Div. with Facit Electronics, a subsidiary of Atvidabergs Industrier of Stockholm. Terms of the agreement call for the manufacture and distribution of Facit electronic computer accessory equipment by Autonetics in North America. The Swedish firm will have similar rights to RECOMP II and NIFTE in the Scandinavian countries. Facit's peripheral equipment includes high speed paper tape punch and reader equipment and a fast direct access magnetic tape unit.

E. A. Holmes, III, director of the Industrial Products Div., is enthusiastic over this cross-licensing agreement. "Facit's excellent peripheral equipment will give us a solid competitive assist in the expanding small computer market," he says. "In the next several months, as part of our licensing agreement, we will also introduce Facit's high speed computer writer. This particular piece of equipment will round out our RECOMP II package and put us in a competitive position second to none," he goes on. Purchase price: of the computer is $95,000; lease: $3,000 per month.

Currently Autonetics has eight sales and service offices in major U.S. cities, but plans call for a total of 26. Also planned is a 60,000 sq ft Electronics Research Center in Anaheim, Calif.

—Michael Murphy
McGraw-Hill News

GE Joins Computer Center Rush

General Electric Co. has become the latest manufacturer of business data processing systems to announce plans for a chain of computer centers. GE says it will equip 11 centers in the next 18 months with either its 225 or 210 machines.

Five of these centers will be ready in 1961; they will be in New York, Boston, Philadelphia, Cleveland, and Chicago. Six more will open in the first half of 1962 in Minneapolis, Seattle, Atlanta, Washington, D. C., Dallas, and the San Francisco Bay Area. In addition, site surveys are underway in seven other cities.

The 210 is a large scale bank data processing unit; the 225, a medium scale, general purpose unit.

The other computer coming off GE's Phoenix, Ariz., lines is the 304, a large scale computer that is made primarily for National Cash Register Co. Actually, NCR designed the 304 and contracted with GE to build parts of it. NCR makes the input-output equipment and also produces a smaller part of the central electronics gear at its Hawthorne, Calif., electronics division plant. GE also makes some models which it labels "GE 304" for sale to other GE divisions.

Harry Wise, head of electronic sales at NCR told CtE last month that GE's moves into computers will not interfere with production of the 304. The arrangement is expected to continue as long as NCR can sell the machines.

GEC Ltd., English Electric Consider Merger Plan

LONDON—

Two of Britain's Big Three electrical equipment firms are now in the talking stage of a merger that would form the biggest such firm in the U.K. A brief statement issued by General Electric Co. Ltd. and English Electric Co. has stated that the contemplated move may come by means of a holding company.

Combined net assets of the proposed company would be $495 million, topping the now largest of Britain's electric firms, Associated Electric Industries, whose assets total around $465 million.

Increased competition and narrowing profits in the British electrical industry are presumed behind the merger. Industry circles in England have heard rumors in recent months that GEC was seeking a mate. The firms' statement said only that they had been considering "the general position of the British electrical indus-

try" and felt that "many activities of their two groups are complementary" and agreed "to explore immediately the practicability of a merger".

GEC is the smaller of the two partners with 70,000 employees and sales last year of $327.6 million. The outfit is not connected with GE of the U.S. (American GE does maintain in London the GE Co. of New York Ltd., an affiliate of the New York-based International GE.) Sales of English Electric were $512.4 million last year; employment 84,000.

Sperry Divs. to Join For Range Group

New York based Sperry Rand Corp. has announced a new cooperative group within the corporation that will make use of the talents of several of its divisions. A Missile Range Instrumentation group will draw on the talents of specialists from the Ford Instrument Co., Remington Rand Univac, Sperry Gyrascope Co., and Vickers, Inc. subsidiaries.

Sperry Rand has estimated the potential market for compatible range instrumentation at more than $1 billion. Complexity of the design problems of range instrumentation is highlighted by the multitalent emphasis. A majority of Sperry divisions may be brought into the picture.

Bendix, Ericsson In Joint Venture Move

Another joint venture company involving an American control supplier and an established European firm (see CtE, Oct. '60, p. 42) has been announced in London. This arrangement brings together the Bendix Corp. of Detroit and Ericsson Telephones Ltd. of London.

The new company, Bendix Ericsson (UK) Ltd., will take over the instrument interests of Ericsson's Instrument Div., which produces electronic and nucleonic measuring instruments and data handling equipment.

News of Other Companies In the Control Field

Texas Instruments, Inc. has established a new subsidiary, Texas Instruments France to manufacture semiconductor devices and components near Nice for the European Common Market.

Precision Instrument Co. of San Carlos, Calif., recently purchased Mag-

netic Industries, Inc., of Palo Alto. The move was designed to augment PI's instrumentation magnetic recorder production with manufacture of related components: toroids, coils, cores, and transformers.

Recordak Corp., Eastman Kodak Co.'s subsidiary in the microfilm and business systems field has established an educational microfilm systems department as its first step into the burgeoning teaching machines market.

Ryan Aeronautical Corp. in San Diego, Calif., has announced two new subsidiary corporations. Ryan Communications, Inc. and Ryan Transdata, Inc. will deal in "a broad range of communications problems" and "in the design and development of data handling equipment", respectively.

General Precision, Inc. of New York has announced that it has engaged Mitsubishi Shoji Kaisha Ltd. as exclusive distributor in Japan for the GPL, Kearfott, and Librascope divisions of GPI.

The Bendix Corp.'s Radio Div. has been awarded a $1.5 million U.S. Navy contract for downrange instrumentation and operational services on the Pacific Missile Range. The contract represents extensions of services performed in the past year.

Friden, Inc. of San Leandro, Calif., has answered the demands of increasing foreign business (now 25 percent of total sales) by establishing a subsidiary sales company, Friden International, S.A., in Fribourg, Switzerland. Friden expects European sales will account for fully half of its sales total within the next 10 years.

Borg-Warner Corp. has expanded its activity in the electronics field by establishing a new Philadelphia based subsidiary, Omnitronics, Inc. The firm will specialize in space electronics equipment, digital communications, data handling systems, and communications terminal equipment.

Aerojet-General Corp., an Azusa, Calif., subsidiary of General Tire & Rubber Co., has purchased a controlling interest in Space Electronics Corp. of Glendale. The purchase was made from Pacific Automation Products, Inc., of which Space Electronics had been a subsidiary.

TRW Computers Co. is the new name for Thompson-Ramo-Wooldridge Products Co., the Beverly Hills, Calif., division of TRW that markets the RW-300 digital control computer.

IMPORTANT MOVES BY KEY PEOPLE

Bratton Moves Up As Imm Resigns at Librascope

New president of the Librascope Div. of General Precision, Inc. is William E. Bratton (photo) who has taken over the post following the resignation of Lewis W. Imm, who launched the company 13 years ago. Bratton, who has also been with the Glendale, Calif., firm since 1947, has been serving as executive vice-president.

Imm resigned to form a new company, Intellux, Inc. in Reseda, Calif. to develop and market miniature electronic components. His firm is expected to work with molecular electronic devices as well as in miniaturization of standard electronic components through the use of thin film techniques. At GPI's request, he'll continue as a special consultant on computer systems development to Librascope.

Bratton became assistant to the president in 1950 and in 1954 was appointed vice-president in charge of engineering, manufacturing, and sales. In addition, when Librascope was joined with three other General Precision Equipment Corp. subsidiaries (GPL, Link, and Kearfott) into GPI, Bratton was named to GPI's board of directors.

Karsch Joins Aeronutronic From GM Defense Post

Former manager for aerospace operation of General Motors Corp.'s Defense Systems Div., Herbert L. Karsch, has joined the Aeronutronic Div. of the Ford Motor Co. as manager of Space Technology Operations' Space Systems. Karsch succeeds Ralph P. Morgan who has been named a special assistant to Dr. Donald P. Duncan, general operations manager of ST Ops at the Newport Beach division.

Prior to joining GM, Karsch was technical director of the White Sands Proving Ground from 1946 to 1956. As an Army Ordnance Corps officer he had been deputy commander of the test center from 1945 to 1946.

Morgan has more than 14 years experience in the fields of advanced weapon and test systems, including a post at Lockheed, prior to joining Aeronutronic, where he was engineering project officer for the X-17.

Piatt, Former IBM Manager, Now Veedor-Root V-P

Donald R. Piatt, at one time manager of engineering of the Time Equipment Div. of International Business Machines Corp., has become vice-president of engineering and research for Veeder-Root, Inc. of Hartford, Conn. He joins Veeder-Root from a position as consultant on electromechanical devices for the Dept. of Defense.

Piatt had been with IBM for 24 years, starting as an engineering trainee in 1933. He has also been director of engineering for Universal Controls, Inc. and vice-president of research and engineering for the Underwood Corp.

Zillman Heads Three Data Divisions at CEC

Jack H. Zillman has become vice-president of the data processing divisions of Consolidated Electrodynamics Corp., a subsidiary of Bell & Howell Co. in Pasadena, Calif. He'll be responsible for operations of CEC's Datalab, DataTape, Transducer, and Electro Mechanical Instrument divisions.

For the past three years, Zillman has been vice-president and general manager of the Pacific Div. of Daystrom, Inc. Previously he was general manager of U. S. Industries Research and Development Corp., president of Whirlajet, Inc., and held various posts at Hughes Aircraft Co. and North American Aviation, Inc.

ISA Names Officers, Awards At Annual Meeting

Along with technical sessions and an exhibition (see p. 30) ISA mem-

bers attending the 15th annual meeting in New York also voted in a new slate of officers and witnessed the awarding of several honors and citations. Dr. Ralph H. Tripp of Grumman Aircraft Engineering Corp., president-elect-secretary for the past year, was named 1960-61 society president.

Philip A. Sprague, president of The Hays Corp. was named president-elect-secretary, and John C. Koch of Conoflow Corp. was elected treasurer.

Departmental vice-presidents elected were Henry J. Noebels, Beckman Instruments, Inc.; E. Albert Adler, United Engineers & Constructors, Inc.; John J. McDonald, Consolidated Systems Corp.; and Francis R. Hoag, B. F. Goodrich Research Center. Five district vice-presidents were also elected. They are: H. Kirk Fallin, Bethlehem Steel Co.; Fred R. Gilmer, E. I. du Pont de Nemours & Co., Inc.; Otto J. Lessa, Hagan Chemicals & Controls, Inc.; Roy Horton, Research Controls, Inc.; and Kenneth S. Vriesen, DeVry Technical Institute.

Among the awards presented were the Distinguished Achievement Award of the society to Dr. Erwin Müller, Pennsylvania State University, for his work in ion emission microscopy; a lifetime honorary membership to Dr. Allen V. Astin, director of the National Bureau of Standards; and the Arnold O. Beckman Award to Billy M. Horton, Diamond Ordnance Fuze Labs of the Army's Ordnance Corps for his developments in fluid amplifiers. Several other awards were presented, and 10 members were made fellows of the ISA.

Other Important Moves

Thomas H. Mansfield has assumed the position of chief engineer with Servomechanisms, Inc. of El Segundo, Calif. He comes to SMI after spending six years with Hughes Aircraft Co., his most recent position being manager of the Guidance and Controls Dept. there. Before joining Hughes, Mansfield was with Tracerlab where he directed the development of nuclear instrumentation.

Gifford K. Johnson, key man in Chance Vought Aircraft, Inc.'s recent diversification moves (CtE, Mar. '60, p. 208) has moved up in the corporation to the post of executive vice-president from a position of president of Vought's Information Systems, Inc. subsidiary. He remains as board chairman of CVA's National Data Processing Corp. In other moves at the Dallas firm, D. J. Simmons was promoted to the new post of chief of electronics systems in the Electronics Div. In the same Vought unit J. R.

WHAT'S NEW

Campbell moved up to the post of chief scientist.

Dr. William J. Jacobi is the vice-president of Litton Systems, Inc. and also general manager of the Guidance and Control Systems Div. The Beverly Hills group is a subsidiary of Litton Industries.

Allen F. Donovan is the newly announced senior vice-president, technical of the Aerospace Corp. of El Segundo, Calif. He was formerly vice-president and director of the Advanced Systems Planning Div. of Space Technology Labs. Other officers named by the budding company are Jack H. Irving (from STL), vice-president for systems research and William W. Drake, Jr. (from Raytheon Co.), as v-p for administration.

Thomas H. Wiancko, founder and former president of Wiancko Engineering Co. of Pasadena, Calif., will be the chief scientist of the Defense Products Group of Daystrom, Inc. Daystrom recently acquired and added Wiancko's company to the group as Daystrom-Wiancko Engineering.

David R. Hull has been elected executive vice-president of Hoffman Electronics Corp. in Los Angeles. His responsibility in the new post will be for the operation of Hoffman's Military Products Div. and for the coordination of the activities of the company's Science Center with other divisions. For the past 10 years Hull has been vice-president of equipment operations for the Raytheon Co.

Dr. Edwin Morris Hudson has joined the Defense and Industrial Div. of Otis Elevator Co. in Brooklyn, N. Y., to head a new human engineering department. His background includes psychological research as an engineer-psychologist working on the Army-Navy Instrument Program (ANIP).

Dr. Herman H. Kurzweg has been named assistant director for Aerodynamics and Flight Mechanics in the Office of Advanced Research Programs of the National Aeronautics and Space Administration. Also named by NASA was Robert G. Nunn, Jr., as special assistant to NASA administrator T. Keith Glennan to advise on communications satellite problems.

ABSTRACTS

Twosome on digital servos

The Navy has sponsored an investigation of the effects of closed-loop quantization of the feedback signal, the optimum form of the computer error output, and the consequences of employing error sampling rates. The results of the investigations are covered in two reports which can be obtained from the Office of Technical Services, U. S. Dept. of Commerce, Washington 25, D. C.:

"The Analysis and Design of Digitally Controlled Instrument Servos", by R. Scheidenhelm, MIT for U. S. Naval Training Device Center, U. S. Navy, 88 pp. Order as PB 161020, $2.25.

"A Simulator Study of Two Digitally Controlled Instrument Servos", by R. Schneidenhelm and Y. Lundh, MIT for U. S. Naval Training Device Center, U. S. Navy, 72 pp. Order as PB 161021, $2.00.

The first report analyzes the effects of time-sampling and amplitude quantization of output and error signals on the performance of a second-order instrument servo to be controlled by a digital computer. Two configurations are considered. One is a high performance type, capable of reproducing signals that include the altitude quantities, such as altitude and rate-of-climb, involved in aircraft control loops. The second configuration employs a logarithmic level-selection scheme for the computer output signal. Application of the design techniques is made to an instrument servo which converts the signals generated in a digital operational flight trainer to the analog pointer positions of the cockpit instruments.

The second report covers the experimental verification of the same two digitally controlled instrument servo configurations that were studied analytically in the report cited above. The physical simulation permitted investigation of the effects of quantization in the output signal and decoded computer drive signal. One servo uses a combination of digital and analog compensation to realize 1) a sine wave response peak of 2 at a frequency of one-fourth of the sampling frequency and 2) a time delay in following a ramp input of one-half the sampling period. The other servo, which has lower dynamic requirements, employs a selection program which reduces the number of drive

ABSTRACTS

signal levels requiring decoding. The selected levels are in logarithmic, rather than linear, sequence. The report contains a complete description of the analog output member, the interconnections with the computer, the computer programs, and comparisons of the experimental results with the theoretical predictions.

Steady light source

From "A Simple Circuit for a Light Source of Constant Intensity", by H. van Suchtelen. Philips Technical Review, Vol. 21, No. 8, 1959-60, pp. 229-233.

In many measurements employing a light source, like photometric measurements of luminous intensity and absorption measurements with a colorimeter or spectrometer, it is important that the light source remain at a very constant intensity. The article describes a simple circuit in which a cadmium-sulfide photoresistor is used to keep the emission of an incandescent lamp at constant intensity.

Rather than merely stabilize the supply voltage to the lamp, it is more logical to stabilize the luminous intensity itself. In the device that is described, the light source is a 6-volt, 5-amp incandescent lamp. The line voltage is first reduced and stabilized by a transformer with a saturated core. A photoresistor in conjunction with five transistors in a bridge circuit regulates the luminous intensity. The intensity remains constant to within plus or minus 1 percent for line voltage fluctuations of plus or minus 20 percent. Furthermore, the intensity varies less than 0.2 percent per deg C change in temperature.

Ore plant control

From "Automatic Control in Mineral Processing", by M. J. Cahalan, Rio Tinto Management Services, and R. Wolski, Elliot Brothers. Paper Group IX 48 presented at the International Mineral Processing Congress, London, April 1960.

The paper discusses the aims of process control and the various steps to be taken to develop a comprehensive automatic control system for a mineral processing plant. Information is given on the application of modern techniques and equipment to some of the many different processes and operations characteristic of this industry. Several of the tech-

niques described resulted from an extensive study of the possibilities of an entirely automatic plant and, while these techniques are not in current commercial use, the associated equipment already exists.

Heat exchangers reviewed

From "A Survey of the Literature on Heat Exchanger Dynamics and Control", by T. J. Williams and H. J. Morris, Monsanto Chemical Co. Paper (Preprint 1) presented under auspices of AIChE at the Joint Automatic Control Conference, Cambridge, Mass., September 1960.

Acting on in behalf of the Instruments and Regulators Div. of the ASME, the authors undertook a search of current literature to critically evaluate available information on dynamics and control of heat exchangers —thereby perhaps enabling the IRD Research Subcommittee to determine the direction future studies should take to correlate equipment design with process dynamics.

In all, 42 published or pending papers were found on the subject, 40 of them having appeared since 1952. The authors coordinate them under the headings of theoretical models, experimental test methods, and automatic control investigations. Besides listing each paper in a bibliography, Williams and Morris further contribute to the study by annotating the papers in tabular form. Here for each reference the authors summarize such data as type of exchanger, fluids, major type of study (theoretical, experimental, or both) type of experimental data, and theoretical solutions. Most important are the accompanying remarks, a paragraph or two for each paper.

More from computers

From "On the Information-Handling Efficiency of a Digital Computer Program", by Herbert Freeman, Sperry Gyroscope Co. Paper No. 60-970 sponsored by the American Institute of Electrical Engineers for presentation at the Joint Automatic Control Conference, Cambridge, Mass., Sept. 6-9, 1960.

The use of a digital computer in a control system forces the designer—for reasons of economy—to devote considerable effort to the development of an efficient program. The efficiency of a program is the measure of the effectiveness with which the program enables a computer of minimum capability to meet the requirements of the system. Computer capability is

ABSTRACTS

measured in terms of speed and word length. For a given system the less capable the computer, the more severe the requirements for an efficient program. Author develops concept of program information-handling efficiency as program figure of merit.

The achievement of a particular cycle time as required by the dynamics of the system, the author shows, can be directly related to the information handling efficiency of the program. Although improvement in information handling efficiency is most readily achieved by streamlining the equations which the program must solve, considerable improvement can also be realized from the proper scheduling of various subtasks of the program.

Digital-input positioning

From "A Digital to Analog Converter for Numerical Control of Synchros", by H. G. Lott. Regelungstechnik, May 1960, pp. 157-162 In German.

The author deals with the application of a three-phase current transformer having a hexagon and a six-phase star winding as a digital to analog converter, translating decimal input signals into proportional voltage components in position control with synchros. For combining the coarse and the fine channel a matrix is required, the working principle of which is explained in detail. Diodes and resistors are used to obtain functional relationships. A method is described for switching small ac currents by means of bistable transmitter circuits.

Printed circuit switch

From "A Versatile Printed Circuit Switch for Application in Laboratory and in Production", by W. H. Hoffman, Jr., U. S. Army Signal Research and Development Lab. Available from Office of Technical Services, U. S. Dept. of Commerce, Washington 25, D. C. as PB 161458, 27 pp., $1.

The report describes a multiple printed circuit switch, readily adaptable to nearly all electronic circuitry needs where printed wiring boards are used to connect electrical components. In kit form the switch is suitable for general lab use in experimentation. In addition, the switch is adaptable to mass production and automatic assembly methods.

NEW BOOKS

Basic computer test

ANALOGUE AND DIGITAL COMPUTERS. *Ed. by A. C. D. Haley, W. E. Scott, and M. G. Say. 308 pp. Published by Philosophical Library, Inc., New York.* $15.

A panel of British experts cooperated in this book, each member contributing a chapter in the field in which he is best qualified. While this approach makes for a good deal of discontinuity of style and some repetition, the editors felt that the duplication was justified by the opportunity to have a different light thrown on a topic by different approaches.

The compendium is intended primarily as a first source of information on computers for newcomers in this field. Directed specifically at the student, it should have value for experienced workers in other fields whose work brings them into contact with computing systems. Numerous references are included to guide those needing more detailed information on specific topics.

Transducer Text

INSTRUMENTATION IN SCIENTIFIC RESEARCH — ELECTRICAL INPUT TRANSDUCERS, *Kurt S. Lion. 320 pp. Published by McGraw-Hill Book Co., Inc., New York.* $9.50.

The title of this book is somewhat unfortunate, as it implies that it is directed exclusively to laboratory scientists and not to engineers. However, as stated in the preface, "technical" instruments are thoroughly covered, and the wealth of information included should make this volume indispensable to those engineers interested in sensing devices for control systems. It is to be hoped that the series promised in the preface will continue to cover all phases in the same style.

The treatment is exhaustively complete in terms of listing, explaining, and comparing various transducers of similar purposes in each of 16 major fields. These are grouped under the main headings: Mechanical (seven subheads), Temperature (one), Magnetic (one), Electrical (five), and Radiation (two). While a few specifically engineering types of transducers are not included, coverage seems quite adequate.

A book of this type can scarcely be rated on readability, and any specialist is likely to find those sections not

NEW BOOKS

closely related to his field to be slow reading. However, the author has made a commendable effort to use simple language to the greatest extent possible. Mathematical complexities are also minimized. Good over-all organization plus nine full pages of subject index make easy the use of the volume for reference purposes. An eight-page author index is also included, though it is of less value for the engineer.

While relatively few refences are later than 1957, the book appears to be thoroughly up to date and is almost certainly the first hard-cover appearance of many of these devices. It seems likely to prove valuable to anyone working in the many fields involving instrumentation.

A. Beerbower

Industrial Text

ULTRASONICS. *Benson Carlin. 350 pp. Published by McGraw-Hill Book Co., Inc., New York, N. Y. $11.50.*

Slanted toward practical engineering design and industrial applications, this newly published book on ultrasonics covers theory and methods of generating waves, outlines circuits and other considerations, and discusses mechanical and electrical design of systems. It treats various phases, from the design consideration of ultrasonic crystals to the experimental measurement of ultrasonic waves in various media, including data on instruments and applications. This revised second edition covers new developments in the testing, cleaning, welding, and soldering of materials and in medical and other applications. It includes new advances in the design of generators, transducers, and transducer tools and joinings and on means of testing equipment.

The book explains changes in the form of matter brought about by ultrasonic agitation in the chemical, physical, and biological fields and describes characteristics of ultrasonic waves important in practical applications. Among the specific topics covered are: wave of dilation, the beam spread at various frequencies from a given transducer size, possible ways of producing ultrasonic waves, and different types of electromechemical converting systems. The book also discusses design considerations of suitable holders for the crystal and explains the use of various instruments such as the interferometer and reflectogage.

MEETINGS

NOVEMBER

Institute of Radio Engineers, 13th Annual Conference on Electrical Techniques in Medicine and Biology. Theme: application of electronic techniques to analytical instrumentation. Sheraton-Park Hotel, Washington, D. C. Nov. 1-2

Sixth Annual Conference on Magnetism and Magnetic Materials, sponsored by AIEE and American Institute of Physics, New Yorker Hotel, New York Nov. 14-17

Symposium on Engineering Applications of Probability and Random Function Theory, Purdue University, Lafayette, Ind. Nov. 15-16

Institute of Radio Engineers, Professional Group on Product Engineering and Production. Fourth Annual Conference, Sheraton-Plaza Hotel, Boston, Mass. Nov. 15-16

Symposium on Combined Analog Digital Computer Systems, sponsored by Simulation Council, Inc. and General Electric Co., Sheraton Hotel, Philadelphia, Pa. Dec. 16-17

Institute of Radio Engineers, Mid-America Electronics Convention (MAECON), Hotel Muehlebach, Kansas City, Mo. Nov. 15-16

American Society of Mechanical Engineers, Annual Meeting, Statler Hilton Hotel, New York Nov. 27-Dec. 2

DECEMBER

Eastern Joint Computer Conference, sponsored by IRE, AIEE, ACM, Hotel New Yorker and the Manhattan Center, New York City Dec. 13-15

Institute of Radio Engineers, Northeast Research and Engineering Meeting (NEREM), Commonwealth Armory and Sheraton Plaza Hotel, Boston, Mass. Nov. 15-17

JANUARY

Seventh National Symposium on Reliability and Quality Control, sponsored by IRE, AIEE, ASQC, EIA, Bellevue-Strafford Hotel, Philadelphia, Pa. Jan. 9-11

16th Annual Symposium on Instrumentation for the Process Industries, Texas A&M College, College Station, Tex. Jan. 26-28

American Institute of Electrical Engineers, Winter General Meeting, Statler-Hilton Hotel, New York Jan. 30-Feb. 3

DESIGN NOTES on
Control by Rotary Switches

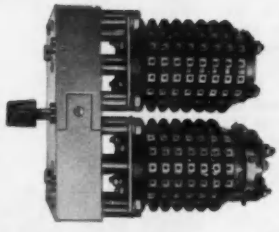
No. 3 of a series

Rotary-switch Applications

One of the simplest applications for a rotary switch is as a single-pole tap switch or a selector switch. In such an application, a single movable contact is connected to one side of the line through a slip ring and, as it is rotated, it engages one stationary contact at a time, thereby selecting the load or circuit to be energized. By leaving certain stationary contacts "dead" or by specifying that they be omitted from the switch in manufacture, provision can be made for "off" positions as required. The form of the movable contact, or in some instances the stationary contacts, can be such as to provide break-before-make (non-shorting) action or it can be made to give make-before-break (shorting) action.

Multi-pole Switching

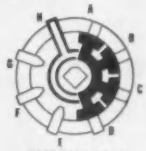
Double-pole switching is easy to accomplish with rotary switches. It is only necessary to gang two similar single-pole assemblies on a common shaft so that both sides of the line are switched when the handle is turned. Ganging of rotary-switch assemblies is relatively easy in manufacture; in fact one advantage of rotary switches is that there is almost no limit to the number of them that can be mounted in tandem for operation by a single



handle. And when that limit is reached, two, three, or more switches can be gear-driven from a common handle.

Complex Circuit Controls

Probably the greatest advantage offered by rotary switches is their adaptability to complex circuit controls. The rotating blades and the stationary contacts can be made in many different forms. For example: multi-fingered blade assemblies can provide cumulative switching from



ASSEMBLAGE 6

ASSEMBLAGE 11

a common feed. Assemblage 6 maintains three circuits while adding one and killing another for each position of the handle. Assemblage 11 permits any one circuit to be opened while the other six are kept closed. Other possibilities depend on blade configuration.

ASSEMBLAGE 9

ASSEMBLAGE 4

By ganging blade assemblies on a single rotor, as in Assemblage 9, two independent circuits can be controlled by a single rotary switch, or double-break, double-pole single-throw switching can be accomplished. Assemblage 4 shows a ganged-blade control in which both shorting and non-shorting contacts are combined to suit special circuit requirements.

From these examples, it can be seen that the control possibilities with rotary switches are almost unlimited. Many other examples are shown in Electro Switch Catalog 101-A which lists four-, eight-, and sixteen-position switches in current ratings from 5 to 200 amperes (depending on circuits) and in a wide variety of styles and mountings.

WHAT'S AVAILABLE IN REPRINTS

The following reprints have been prepared to make important reference-type editorial material available to CONTROL ENGINEERING readers in convenient filable form. Single copies of any reprint can be obtained at the nominal cost listed below by circling the corresponding numbers on a reader service card, p. 189. Don't send money with card, we will bill you later. For multiple copies write Reader Service Dept. Quantity rates will be quoted on request.

505—The Basics of Optimum Response Relay Servos, 17 pp. Three part series summarizes all of the important design techniques that have been used to optimize the response of relay servos. The reprint describes the development of the optimum switching criteria, and outlines the progress that has been made in implementing this theory with hardware for second-order and higher-order systems. Extensive references provide a guide for further study. 50 cents.

504—System Characteristics of Modern Guidance Techniques, August 1960, 22 pp. In this special report five experts from three companies cover the system characteristics of inertial navigators, guidance radars, Doppler radar techniques, modern techniques in celestial navigation, and perceptive guidance systems. 65 cents.

503—How to Determine Stream Analyzer Dynamics, 8 pp. This package of two articles shows how analyzers can introduce dynamic errors, how to determine analyzer dynamics, and how to improve performance. The instrument used is a differential refractometer but techniques can be extrapolated to other types of analyzers. 40 cents.

502—Survey of Dynamic Display Techniques, 20 pp. The function of these newly developed techniques is to put up-to-date information in the hands of human operators of control systems when the information changes at a high rate. Both basic approaches and commercial hardware are discussed for cathode ray tube displays, optical systems, and miscellaneous devices ranging from TV pickup to matrix cells. 50 cents.

501—Six Transducers for Precision Position Measurement, May 1960, 6 pp. Explains operation and gives practical application hints for six precision position transducers: pin-and-pawl mechanism, magnetic bench-mark system, resolver-type transducer, electrostatic transducer, coded-disc devices, and diffraction gratings. 30 cents.

(Continued on page 214)

REPRINTS cont'd

500—Ready Reference Data Files—I, II, III, 76 pp. The feature here is a special rate for those who purchase all of the Data Files published in CONTROL ENGINEERING through April 1960. The 36 articles included in this package cover analysis, design, and application short-cuts for all phases of the control field. Everyone can use this timeless reference material. $1.35.

499—Ready Reference Data Files—III, 28 pp. Includes the third dozen Data Files published in CONTROL ENGINEERING. Topics range from control of metal properties with eddy currents to electrically signaled valve actuators to stabilization of sampled data systems. 60 cents.

498—Ready Reference Data Files—II, 24 pp. Includes the second dozen data files published in CONTROL ENGINEERING. Topics covered range from analyzing hydraulic servos graphically to using silicon diodes as protective devices. 50 cents.

497—Ready Reference Data Files—I, 24 pp. A must for every control engineer's library. Includes the first 12 data files published in CONTROL ENGINEERING—a diversity of topics from system reliability through the cost of industrial temperature-measuring systems. Each one gives a method of solving a particular problem. 50 cents.

496—How to Specify Instrument Accuracy, 8 pp. This basic reprint is aimed at helping the user and maker to develop clear and mutual agreement on allowable instrument errors. Discussions of uncertainties of zero, scale factor, and instantaneous slope aid in the intelligent specification of allowable errors and preferred test procedures. 40 cents.

495—Transparent Template for Designing Servo Compensators, November 1959, 3 pp. plus template. Includes transparent decibel vs phase angle template on clear acetate in addition to three-page Data File outlining development of template and showing its use through sample problem. 75 cents.

494—How to Use the Root Locus in Control System Design, 12 pp. Another reprint that translates theory into practice. Eight simple rules make locus construction easy, even including the effects of distance-velocity lags. Articles show how to interpret the locus diagram, how to determine transient response, and how to use locus techniques with multiloop systems. 45 cents.

493—Complete Analysis Instrumentation Series, 112 pp. Special rate for those who order all three parts (I, II, and III) of Analysis Instrumentation Series: 17 percent discount on 112 pages of timely technical information for process control engineers. $1.75.

492 — Analysis Instrumentation — III — Electrochemical Methods, Mass Spectrometry, Continuous Viscometers, X-Ray Techniques, K-Capture, Physical and Chemical Property Testers, Emission Spectroscopy, 48 pp. Reprint includes last nine articles of Analysis Instrumentation Series. 90 cents.

(Continued on page 217)

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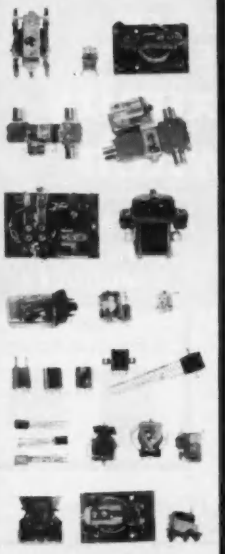

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AM/2C/12VD	100	12 VDC	DPDT 2 amps

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REPRINTS cont'd

491—Analysis Instrumentation—II—Refractometers, Infrared Analyzers, Ultraviolet Analyzers, Colorimetry, 32 pp. This includes the second group of four articles of the Analysis Series. 60 cents.

490—Analysis Instrumentation—I—Nuclear Magnetic Resonance, Chromatography, Radioactivity, 32 pp. Reprint consists of first 4 articles of Analysis Instrumentation Series: a general introduction and detailed discussions of the three analysis techniques. Emphasis is on basic principles, practical tips, and the use of these techniques in automatic process control. 60 cents.

489—Fundamentals of Multivibrators, 12 pp. Multivibrators are the electronic equivalent of the double-throw electromechanical relay and can perform substantially the same functions (memory, logic, gating, counting), but at enormously higher speeds. They can be built around vacuum tubes, transistors, square-loop magnetic materials, neon tubes, thyratrons, and cryotrons. This reprint covers a broad selection of multivibrator circuits. 45 cents.

488—A Roundup of Control System Test Equipment, 24 pp. Specialized control system test equipment divides into three classes: 1) devices that only generate a test signal, 2) systems that both disturb the system and provide a means for evaluating response, and 3) devices that only evaluate control system response. 60 cents.

487—Survey of Ac Adjustable-Speed Drive Systems, June 1959, 16 pp. Regarded as constant speed devices, multispeed ac actuators actually take many efficient forms. The recent resurgence of interest in these ac adjustable-speed systems prompted this comprehensive coverage of pole-changing techniques, armature resistance control of wound-rotor motors, frequency changing, slip-frequency injection, and the use of eddy-current couplings. 50 cents.

486—A New Way to Select the Best Control Valve, 16 pp. This three-article reprint takes a fresh look at the problem of specifying process flow control valves. The author gives rules for selecting the right valve characteristics based on static and dynamic considerations, takes into account the influence of piping on valve performance, and tackles the problem of sizing valves for maximum flow and for control rangeability. 50 cents.

485—Fundamentals of Tie-Motor Control, 12 pp. Although high powered synchro-tie systems have been around for a long time, only recently has enough experience been logged to put their design on a scientific, rather than cut-and-try basis. This reprint examines the types of motors that can be used in the light of the application characteristics, and considers the special circuit designs that are required. 30 cents.

484—Applying Phase-Plane Techniques to Nonlinear System Design, 16 pp. This series of three articles is designed to teach the use of phase-plane techniques to work-

(Continued on page 218)

REPRINTS cont'd

ing system designers, on a practical rather than theoretical basis. It tells how to construct a phase-plane plot, interpret a plot in terms of system performance, and synthesize nonlinear systems using phase-plane techniques. 50 cents.

483—Economics in Control, December 1958, 24 pp. A special report covering the economic aspects of modernizing with control systems. It starts off with a guide to the financial factors of modernization, then tells the control engineer how to spot opportunities where the addition of instrumentation and control equipment will earn money, and concludes with nine case histories showing specific benefits of modernizing with control systems. 50 cents.

482—Static Switching Devices—New Tools for Industrial Control, May 1957, 28 pp. An independent consultant analyzes the complete field of industrial static-switching systems. Starting off with a review of basic switching logic, he covers circuit characteristics of the fundamental devices, commercially-available systems, actual applications, etc. 50 cents.

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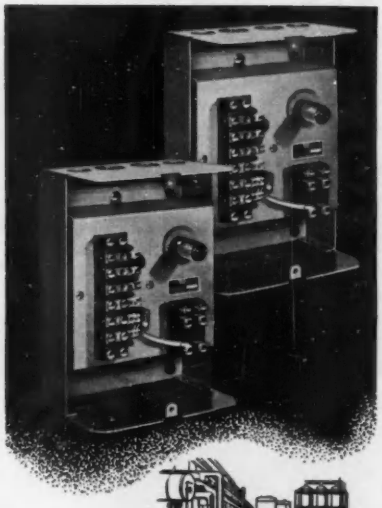

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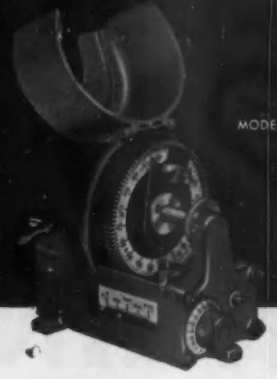

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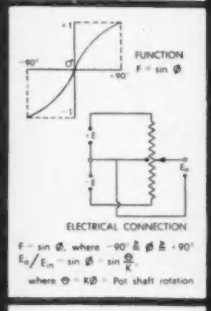

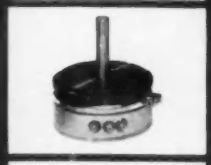

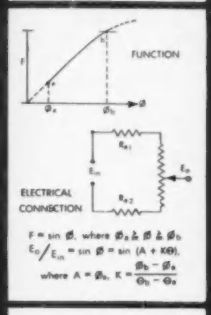

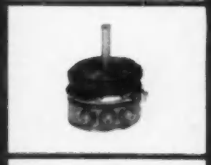

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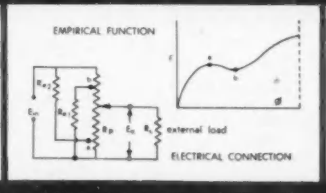

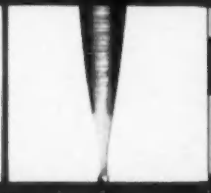

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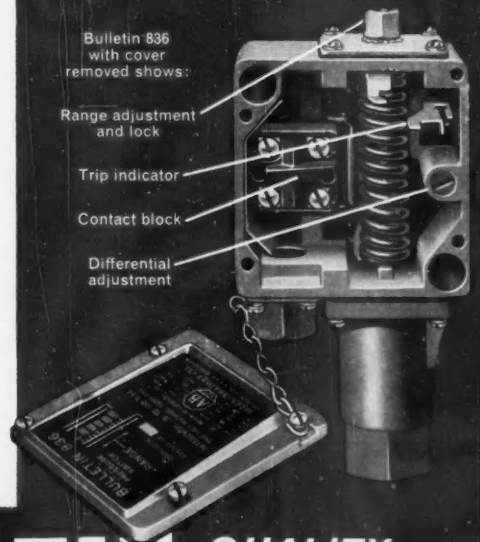

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